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BIOLOGICAL DISCOVERIES

AND

PROBLEMS.

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BIOLOGICAL DISCOVERIES AND PROBLEMS.

THE contents of the following pages are designed to be a repetition and an expansion of certain lectures upon Biology delivered by the writer, at South Place Chapel, Finsbury, in the year 1880. The volume, like the lectures, is designed to make the minds of students more familiar with certain of the most recent biological discoveries, with the large problems in respect to living beings that are under discussion to-day, and with the precise meaning of the scientific terms used in narrating the discoveries and in discussing the problems. These terms are indeed becoming so largely part of ordinary conversational English that it would seem well to endeavor to render their significance as clear as possible to those who are doomed to use them and to hear them used. Much originality of matter will therefore neither be expected in these pages nor will it be forthcoming. The writer desires to play the part of intellectual middleman, and present the discoveries, the definitions, and the theories of the great thinkers upon living things in condensed and, it is hoped, in simple form before those who may not have the time to study the masters at first hand. The plan of work will be as follows. I. General introduction. II. Science and its divisions. III. Matter and motion. IV. Biology. V. The terms employed in the study of Biology. VI. Morphology. VII. Physiology generally. VIII. The special physiology of Reproduction. IX. Development. X. Ætiology. XI. The evolution of Life.

CHAPTER I.

GENERAL INTRODUCTION.

A. *How and why.*—Various definitions of man have been suggested. It is believed that amongst them, up to the present time, the definition of Man as a questioning animal has not appeared. Of the multitudinous queries ever rising to the lips of humanity perhaps the two most frequently repeated are, How and Why. We are always questioning as to the manner and the causes of things. Unfortunately in too many cases the question as to causes precedes that as to manner. The proper sequence is, first, In what manner do these phænomena occur? then, What is the reason of them? The young are all too ready to attempt to give reasons for things ere they have in any way fully understood the things. And what is true of the young individuals is true of the youth of the world's thought. The early thinkers were far too anxious to explain the origin of things ere they understood the nature of the things. Hence theories as to the universe before the parts of the universe and their relation one to another were at all comprehended. But to-day, after some centuries of patient enquiry into the manner of phænomena, after much answering of the query, "How?" it is possible to some extent at least to give some answer to the question "Why?" and to attempt to explain the paths along which phænomena have moved in reaching present conditions. Or looking at the matter from another point of view, collection of facts must precede generalisation. The tendency of youth is to form generalisations from few facts. The aim of the scientific thinker is to collect a large number of facts and thence to arrive at the one large, general idea running through them all, linking them all together. Many facts have been ascertained. Their number hourly increases. The time for generalising in some cases at least has come. Hence in this volume though the account of the manner of phænomena, the recordal of facts will not be wanting, yet will this be in the main subsidary to the presentation of some of the chief generalisations that have been made in recent times.

B. *Teleology.*—The usual reply to either of the important questions to which reference was made under the last head is "g. o. d." This is considered generally sufficient to satisfy the enquiring mind of the child and indeed of the adult. Assuming the hypothesis of a personal, intelligent, planning and directing god, everything is referred to as the outcome of his will and design. And this is Teleology, an order of thought, if it can be dignified with that name, fittingly derived from τηλε, afar off. For in Teleology the thinker looks so far off for a cause or an explanation of that which is, that he generally fails to see what is immediately under his nose. In the work lying before us this method of explanation will be entirely rejected.

C. "*Objects of structures.*"—Rejecting thus all teleological explanations, it is evident that the frequently recurring phrase, "the object or purpose of certain organs or structures" can no longer be used by us. It was, and in some cases still is, the fashion to speak and write glibly enough that the purpose of certain parts is to perform certain functions. Thus the object of the peculiar structural arrangements of an Orchid flower would be said to be to enable the visiting insect to obtain honey, and at the same time to cross-fertilise the Orchids. Such a phrase as this, implying as it does, a directing agent outside Orchid and insect alike, cannot be employed by us. All we can say is, that certain results follow at the present time from particular structural arrangements. And we shall see reason to believe as we pass on in our work that the structure of parts is by no means the cause of their functions. Nay, the reverse would appear to be the truth, and it will be shown in the sequel that in all probability function is the cause of structure, and that the peculiar arrangements in the Orchid flower and in the insect-head are determined by the functional relationships between these two forms of living beings. In brief, function is the cause of structure, not structure the cause of function. We must therefore carefully avoid on every ground the inaccurate phrases as to the purpose of certain parts and use the more accurate statements as to the results flowing from certain special arrangements of structures.

CHAPTER II.

Science and its Divisions.

A. *Science.* It is here needful once again to call to mind what is meant by the greatly misused word Science. Derived from *scio*, I know, it has for significance "the sum of all knowledge."

B. *Its divisions.* An old world distinction is still tolerated between those branches of Science that have to do with matter and those that are supposed to have to do with mind. Hence division by many of the sciences into (1) Physical or Natural Sciences (from φυσις, or from *natura*, nature), having to deal with matter; (2) Metaphysical or Supernatural Sciences (from μετα, beyond, or from *super*, above), having to deal with mind. To the present writer no distinction between these two sets is known. Mind is so essentially a function of matter under particular collocations that he is quite unable to make any fundamental separation of the study of mind from the study of matter. If mind-study is to be fundamentally distinguished from matter-study, and is to be labelled Metaphysical, while the latter is only to be named plain Physical he must claim place by the side of Metaphysics for the study of contractility, of vision, of bile-secretion, of multitudinous other functions. For it would seem that contractility is not more a function of muscle and of protoplasm, vision is not more a function of certain arrangements of matter known as eyes, bile-secretion is not more a function of certain arrangements of matter known as hepatic or liver cells than is mind a function of certain arrangements of matter known as cerebral or brain structures. It is fully time for us to recognise that the old distinction between mind and matter, between Metaphysics and Physics no longer exists. The sole object of man's study is matter in its various forms, and motion as affecting that matter.

The old-fashioned division of the objects of man's study is now given under protest, not against the order of succession, but against the division into two main branches :—

Science.
- Physical or Natural...
  - Mathematics.
  - Physics.
  - Chemistry.
  - Geology.
  - Biology.
- "Metaphysical" or "Supernatural"...
  - Logic.
  - Mental Philosophy.
  - Sociology.

c. *Consideration of each of these divisions of science.*

(1) Mathematics. The foundation of all science. Its derivation from μαθημα, the thing to be learned, points to this position. No one of the sciences following can be studied with full profit by one unacquainted with the principles of mathematics. In fact, it may be said generally that complete comprehension of any one of the subjects named in the above list involves acquaintance with each of its predecessors. Mathematics is the study of number, quantity, figure.

(2) Physics. φυσις = nature. The study of facts true of nature generally: not of any special kind of matter. Thus facts relating to minerals alone, or to plants alone, or to animals alone do not come under the range of Physics. But facts true of minerals, plants and animals come within its domain. That there are three forms of carbon—viz., diamond, graphite and charcoal—is not a fact of Physics. Neither is the statement that ovules are ripened by pollen, nor the statement that a man has seven neck vertebræ. But the statement that all bodies attract one the other expresses a fact that belongs to Physics. Strictly, the study of Physics is the study of distribution of motion in the universe. This will be more intelligible when the meaning of the two terms Matter and Motion is rendered clear.

(3) Chemistry. No very satisfactory derivation of this name is known. Chemia, the old name for Egypt, and χυμος = a juice or liquid, have been suggested. It is the study of the composition of bodies. In fact, in dealing with Chemistry we investigate the forms of matter entering into different bodies. And in the fact that the study of Physics or of distribution of motion precedes that of Chemistry or of distribution of matter we have another

illustration of the fact to which already reference has been made, that change of function precedes change of structure always.

(4) Geology, from γη, the earth, is the study of mineral matters or matter in its most lowly organised form. Here rocks and stones, though let it be remembered rocks and stones that are often the product of animal or vegetable bodies, are the objects of study.

(5) Biology, from βιος, life and λογος, science is the study of the phænomena of living beings. This will be our especial study in these pages.

(6) Logic from λογος, is the science of reasoning. At present the capacity for reasoning is said to be restricted to animals. Hitherto no evidence has been forthcoming entitling us to believe that plants reason. Hence Logic is a special branch of Biology that has not up to the present had to do with beings other than animal, and has as yet extended its researches but little beyond man.

(7) Mental or Moral Philosophy is the study of mind or the especial function of brain matter. This science, also in its infancy, has at present only investigated with any degree of fulness or accuracy the brain-functions of the highest animal.

(8) Sociology is the study of plants and animals in their complex relationships one to another. It studies not so much the individual as the aggregate. This branch of science also has been confined in the main to the relationship of man to his fellows, though the recent investigations of Darwin, Büchner, Forel, Huber, Moggridge, demonstrate to us very forcibly that this study will at least have to take into account ants and their habits, and probably yet other instances of animal societies.

CHAPTER III.

MATTER AND MOTION.

THE relationship between the chief divisions of Science has been pointed out. From that which has been said already it will be understood that an accurate knowledge of Biology implies acquaintance with the general principles of other branches of Science. This will be rendered yet more evident if we commence our investigation of Biology by explaining certain general physical principles, the due comprehension of which is essential to the understanding of problems that relate to living beings.

A. Work and Energy. B. Physical and Vital phænomena. Under A. will be studied matter, motion, work, energy, conservation of energy.

A. *Work and Energy.*—(1) Matter and Motion.—(*a*) By matter we mean the substance whereof the things in the universe are composed. It has various forms, but the general name of matter is employed to include all. (*b*) Motion is change of place. When matter is made to pass from one position to another, it is made to move. Of this motion there are two kinds. (i.) The ordinary movement, as when a cannon-ball is hurtling through the air. This form of movement familiar to us every moment of our lives, is the movement of large masses, and hence is known as molar motion (*moles*=a mass). (ii.) But suppose the cannon-ball strike against a granite wall, and fall to the ground. Its molar motion ceases. It disappears apparently without any trace remaining thereof, for the granite wall, save for a few casual chips flying hither and thither, has not moved. Touch however the wall or the cannon-ball. Each is *hot.* Heat has been given forth and the physicist will tell you that this heat is a form of motion. It is not, however, a form of motion of masses, or of molar motion, but of the very minute particles of bodies. Hence it is known as molecular motion, from *molecula*, a little mass. Of this form of movement heat is not the only example. Electricity, magnetism, perhaps life are instances thereof.

The universe then is made up of matter in a thousand forms. The change of position of matter is motion. This also is manifold, but two main divisions are known. Movement of masses or molar motion, movement of molecules or molecular motion. The endeavor will be made in these pages to translate all the phænomena of living bodies into terms of matter and of motion.

(2) Work.—When a heavy weight is raised from the ground to a certain height, as when for example it has been placed upon a table, a certain quantity of matter has been caused to move through a certain distance. A certain quantity of work has been done. Work is the moving of matter. To move a piece of matter, however small it may be, through a definite space, however small that space may be, is to do work. In considering the amount of work done in any given instance two things present themselves. The first is the amount of matter that is moved. The second is the distance through which it is moved. The greater the amount of matter that is moved the greater the amount of work that is done. More work is done when a cannon ball is lifted from the ground on to a table than when a bullet is lifted from the ground on to the same table. Again, the greater the distance through which the quantity of matter is moved the greater is the amount of work that is done. More work is done when a cannon ball is hurled a distance of a mile than when it is simply carried across a room. Hence the amount of work done depends upon, or in mathematical language varies as (*a*) the mass or quantity of matter moved, (*b*) the distance through which it is moved. To measure Work, therefore, we multiply the number representing the quantity of matter moved by the number representing the distance through which it has been moved. Thus we obtain an abstract number that may be taken to represent the work done. If a mass of 4 grams is carried a distance of 5 metres, $5 \times 4 = 20$ represents the work done. If a mass of 20 grams is carried through 3 metres, $20 \times 3 = 60$ represents the work done. These two numbers 20 and 60 are not concrete. They are numbers representing the amount of work done in the two

cases, and they show that three times as much work is done in the second case as in the first. Work, therefore, by definition is the moving of matter. It is measured by multiplying the number representing the mass or quantity of matter moved by the number representing the distance through which the mass has been moved.

(3) Energy.—The capacity for doing work. A cannon-ball speeding from the mouth of a gun has energy. It has the capacity for moving matter a certain distance. Thus it may batter down a wall and scatter the fragments in all directions. The energy of a cannon-ball in this case is that form of energy known as kinetic (κινησις=motion) The energy wherewith a falling stone smites the earth, the energy of an electrical battery in action, or the energy of a fire causing a bar of iron to expand and moving the atoms of that bar farther from each other, each of these is kinetic energy. But consider the case of a stone supported on the top of a tower, or of the zinc and copper and sulphuric acid of the battery ere they are brought together, or of a piece of water with its latent heat. The stone has the capacity for work, and if pushed off the summit of the tower will fall and do work. The metals and acid of the battery have the capacity for work, and if brought together will do work in transferring the Hydrogen matter say of acidulated water away from the Oxygen matter. The water has the capacity for work, and if it is turned into ice will liberate a quantity of heat that can be utilized to set matter in motion. And to that form of energy or capacity for work possessed by the stone on the top of the tower, by the zinc, copper and sulphuric acid before they are brought into contact, by the water with its latent heat, is given the name "potential energy." It is capacity for work, not yet in action. There is the possibility but not yet the actuality. Energy is the capacity for doing work. If the body is actually at work, its energy is kinetic. If it is waiting to be at work, its energy is potential.

(4) Conservation of Energy.—It is impossible to conceive of the creation of matter or of motion. It is equally impossible to conceive of the destruction of matter or of motion. The creation or the destruction of either is unthinkable, for to think of the creation of matter you have to connect in thought something (matter) with nothing. You have to

conceive of a time when matter began to exist, and that conception must involve the conception of a time when nothing existed. So that to think of the creation of matter or the creation of motion, it is necessary to connect together two ideas, one of which is unthinkable. The same fatal objection applies to the conception of the destruction of matter or of motion. Matter and motion are to the scientific student eternal. They may be changed into a thousand different forms, but they cannot be destroyed. The matter of a human body may become the matter of certain gases, the products of its decay, but there is only a change of matter, not a creation or a loss. The nerve and muscle forces of that body may cease to act, but heat, chemical and electrical force, are liberated during the decay of the dead body. There is only change of motion, not creation or loss. And the truth thus deductively reached is also established inductively. Experiment shows us that with all the endless transformations of matter and of motion there is never any loss, never any gain. The amount of matter and the amount of motion in the universe is probably the same to-day as it has been and as it ever will be. It is only the distribution of these twain that varies, never the actual quantity of either.

The clearest enunciation of this truth was made some years ago by Grove. He it was who first distinctly stated the great principle of the conservation of energy. He pointed out that if a piece of zinc and a piece of copper be placed in sulphuric acid, chemical action (one form of motion) takes place. Carry wires from the zinc and the copper and bring their points near one to the other. An electric spark passes. Electricity (a second form of motion) is evolved. The spark is bright and hot; noise is heard as it passes. Light and Heat and Sound (forms of motion) are evolved. Wind the conducting wire round a piece of soft iron and whilst the electrical current passes the iron attracts other pieces of iron. Magnetism (a form of motion) is evolved. Place the ends of the two conducting wires in connexion with a fresh muscle removed from an animal. The muscle contracts. Life (a form of motion) is evolved. Finally, immerse the ends of the two wires in acidulated water and the Hydrogen and Oxygen of the water are liberated therefrom. Chemical Action (a form of motion) is again evolved. Thus are all these different forms of motion linked together. And further the quantities of each evolved are definite and calculable. For every gram of zinc dissolved in the battery a definite and measurable amount of electricity, or of light, or of heat, or of sound, or of magnetism, or of life, or of chemical action is evolved. There is absolutely no loss, absolutely no gain. And the conclusion forced upon us by these and multitudes of kindred experiments is that whilst infinite transformations of matter are possible and occur, and infinite redistributions of motion are possible and occur, of creation or of destruction of the one or of the other at any time or under any circumstances there is no evidence whatever.

B. *Physical and Vital Phænomena.*—From that which has been said it will be gathered that a striking distinction has been drawn between the phænomena met with in inanimate bodies and those encountered in living beings. From that which has been said it will be gathered that many thinkers regard this distinction as non-fundamental. Whilst the mass of mankind still look upon the modes of motion noticeable in plants and animals as not translateable into ordinary physical language, the judicious few speak of these vital phænomena as of similar nature to those seen in the inanimate world. To them, between the modes of motion observable in minerals and the modes of motion observable in plants and animals, the main difference is one of degree. It is true that at present we have nothing in the mineral kingdom that seems precisely to correspond with the sensory and motor organs and functions of plants and animals, but these functions can be set in action by certain more general physical forms of motion, and can produce certain more general physical forms of motion, such as electricity and heat. Indeed, the further investigation advances, the more thoroughly does it establish the close relationship between the so-called "vital" and physical phænomena, and it would appear possible that in the hereafter the whole of the complex series of actions that take place in the life of an individual, and even in the yet more complicated life of a society, will be reducible to mathematical formulæ.

That the tendency to separate the phænomena of the inorganic from those of the organic has been, and that this separation cannot be maintained, are alike shown by the old names for the chief divisions of the study of Chemistry and by the more modern synonyms. Once on a time a distinction was made between Inorganic Chemistry, or the Chemistry of mineral bodies, and Organic Chemistry, or the Chemistry of Organic bodies, such as plants and animals. Then we were told that it would be impossible for man ever to make any of the many organic substances. He might hope to continue making Oxygen and Ammonia and mineral acids and so forth, but he must never aspire to the production save through the aid of plants and animals of sugar, starch, or alcohol. Thus very complacently the foolish ones. But their wiser fellows, who knew that Science has but few Nevers and Impossibles, who therefore were not arrogant but patient and hopeful, set to work in their laboratories. And, behold, substance after substance that was organic, a "vital product," never to be made by man has been prepared by him from mineral things. Patient, imperturbable nature, waiting with her open secret all through the centuries that are her heart-beats until the true worker come!

In 1828, Wöhler sets to work upon Ammonium Cyanate. The chemists give this salt for formula $(H^4 N) CNO$. And, from this, Wöhler produces $C H^4 N^2 O$. Add up the atoms of Carbon in the formula of the salt and in the new formula. Do the same with the atoms of Hydrogen, of Nitrogen, of Oxygen. The number of atoms of each element in the two bodies is the same. And yet the one is Ammonium Cyanate, a mineral, and the other is Urea, a product of animal bodies these many centuries, made to-day artificially in the laboratory.

Wurtz, and Kolbe, and Berthelot have all been busy in this new field of work. Let us see what they have done. Charcoal and Sodium Carbonate (both minerals) are mixed together. Air (which contains nitrogen gas, a mineral) is passed over the mixture. Sodium Cyanide results. In symbols, for the chemists:

$$4C + Na^2 CO^3 + N^2 = 2 (Na CN) + 3 CO.$$

Then the Sodium Cyanide, NaCN, is changed into Mercury Cyanide, $Hg (CN)^2$. This heated expels its Cyanogen gas, CN. This gas Cyanogen treated with water yields Ammonium Oxalate.

$$2 (CN) + 4 (H^2 O) = (H^4 N)^2 C^2 O^4.$$

And Ammonium Oxalate treated with an acid, as *e.g.*, Sulphuric Acid, yields a corresponding Salt of Ammonium and free Oxalic Acid (an organic body).

$$(H^4 N)^2 C^2 O^4 + H^2 SO^4 = (H^4 N)^2 SO^4 + H^2 C^2 O^4$$

(Oxalic Acid).

Or once again, electric sparks are discharged between Carbon points in an atmosphere of Hydrogen. Ethine, $C^2 H^2$, a compound of Carbon and Hydrogen is formed. This, in contact with Copper and Hydrogen just freed from one of its compounds, seizes two more atoms of Hydrogen, and becomes Ethene or Olefiant Gas, $C^2 H^4$. Ethene, acted upon by Sulphuric Acid, gives a complex Sulphate of Ethyl ($C^2 H^5$) and Hydrogen.

$$C^2 H^4 + H^2 SO^4 = C^2 H^5 H SO^4.$$

And this complex body, treated with water, yields alcohol.

$$C^2 H^5 H SO^4 + H^2 O = H^2 SO^4 + C^2 H^6 O \text{ (alcohol).}$$

And thus men in the laboratories to-day are slowly building up organic substances from inorganic, even as possibly in the dim remote past those were built up from these by nature.

Therefore the name Organic Chemistry is laid upon one side for the most part to-day, and ere long will be wholly abandoned. In its place we read of the Chemistry of Carbon Compounds.

Nevertheless, the advanced student is pained and the beginner misled by finding in some books laying claim to be text-books upon Chemistry such phrases as this: "Organised bodies are organs or parts of organs which are essentially products of vitality, and there is not the slightest prospect of their ever being produced by artificial means." ["Fownes' Organic Chemistry," edition of 1877, edited by Henry Watts, p. 2.] Borrowing the phrase of Professor Huxley we might as well say that the arrangement of wheels in a clock is a product of horologity as that starch or albumin are products of vitality.

And if it be urged that the phænomena occurring in living bodies are strange and unpredicable from the properties of the matter whose collocation forms the living body, let it be answered that no less strange and unpredicable are the phænomena that occur in physics and chemistry. No one could anticipate that two forces, acting simultaneously on a particle, would urge it along a line corresponding with the diameter of a parallelogram whose two sides represented the two forces. No one could anticipate that the pouring of a yellowish liquid, nitric acid, on copper would produce a green liquid, not acid, not metallic, and, a gas, at first colorless, and later, on contact with colorless air, red-brown, but in neither aspect liquid or metallic. No one could anticipate that placing zinc and copper in sulphuric acid, connecting them by silver wire, and breaking that wire across, electric sparks with light and heat and sound would leap from end to end of the disparted wire. Yet all this does occur, and later on, when our descendants have studied the matter of which living bodies are composed as closely as we have studied forces acting on a point, copper and nitric acid, zinc, copper and sulphuric acid, as certainly as they now anticipate the fulfilment of the principle of the parallelogram of forces when two forces act on a body, or the production of copper sulphate and certain oxides of nitrogen from copper and nitric acid, or electricity from a Daniell's cell, so certainly will they anticipate power of movement, of sensation, of reproduction from certain arrangements of matter.

CHAPTER IV.

BIOLOGY.

ALTHOUGH the evolutionist holds that in the course of ages out of the few have evolved the many, and to him attempting to survey the universe in the past as well as in the present, all things merge one into another, and hard and fast lines of demarcation are impossible to be drawn, yet he recognises the great differences that may in time obtain between bodies that have varied along different lines, though their original forms may have been the same. Hence he makes use of the exceedingly convenient phrases known as definitions, whilst he is conscious that not a few of such definitions will not hold in relation to the extreme members of the series they are intended to define. Whilst, therefore, we feel assured that in their lowest forms living things graduate into the non-living and that no definition will completely include all that we name organic to-day whilst it excludes all that we name inorganic, it is convenient, nay necessary, to adopt some definition that will point out the most essential differences between the majority of living forms and the majority of non-living forms.

A. *Definition of Life.*—Of the multifarious definitions of life that have been suggested, only a few of the most notable will be mentioned. They will be those of Schelling, of Richerand, of Bradlaugh, of De Blainville, of Lewes, of Spencer.

(1) Schelling.—Life is the tendency to individuation. It has been pointed out ere now that this definition includes crystallisation. It may be said, in passing, that probably no definition can be framed that will exclude the phænomena of crystallisation. But to the writer another objection seems to apply to the above definition. The use of the word "tendency" would appear to be objectionable. A definition of life that only states its "tendency" does not seem suf-

ficient. Such definition must contain a statement as to what actually does occur not alone as to what tends to occur.

(2) Richerand.—The collection of phænomena which succeed each other during a limited time in an organised body. To this it has been objected that the decay of a dead body, as a dead animal or plant, fulfils all the necessary conditions required here. The series of phænomena that succeed each other during the limited time that elapses ere the organised tree or the organised man disintegrates into simple binary compounds, such as carbon dioxide (CO^2), water (H^2O), and ammonia (H_3N), these are not phænomena of life, and yet they are included in the definition of Richerand. Another objection, as it seems to the present writer, is that his definition appears to beg the question. It does not appear accurate to use in a definition of life the phrase "organised body." For the organised body is one that has organs. And an organ is a part that performs a definite function; it is functionally active, *i.e.*, it is alive. Hence there would seem here to be a case of *petitio principii.*

(3) Bradlaugh.—The total normal organic functional activity of each animal and vegetable. Here also it seems to the present writer is a difficulty akin to that encountered in the definition of Richerand. The word "organic" seems to imply life. The names animal and vegetable labor under the like disadvantage.

(4) De Blainville.—A twofold internal movement of composition and decomposition at once general and continuous. It has been urged that according to this a galvanic battery must be alive, for certainly within it is "a twofold movement." The Zinc Sulphate is composed: the Copper Sulphate, if it be a Daniell's battery, is decomposed. The movement is general for all the matter in the cell is concerned, and it is continuous for it ceases not until the matters are removed from collocation with each other. And yet, at present, no one would call a galvanic battery alive.

(5) Lewes.—The series of definite and successive changes of structure and composition taking place in an individual without loss of identity. This introduces in its last four words a new and important element. "Without loss of identity." The man or woman reading this page is the

same individual who ten, twenty, thirty or more years ago would have flung the book aside as "dry," or perhaps as "atheistical." He or she is the same that as a child would have very wisely preferred a game, or, as a Christian, would have preferred a prayer-meeting to the discussion of difficult problems. And yet not one atom of matter in the reader of to-day entered into the composition of the child of years ago. The piece of chalk in the cliff of to-day is made of the same matter as the piece of chalk that was deposited from the surcharged sea centuries ago. The dead things are the same yesterday, to-day and for ever. Not so the living. With them there is infinite change and yet no less of identity. But the definition of Lewes seems to ignore one thing in living bodies as important as the thing it recognises. It refers to change of "structure and composition" but not of function. It deals with the matter transformation but not, apparently, with the motion changes.

(6) Spencer.—Surveying the two life functions that are most widely apart, the one the most general in living bodies, the other the most special, the two functions of digestion and of reasoning, Herbert Spencer shows that both involve changes: that the changes are successive and also simultaneous: that they imply changes from the homogeneous (say the food of animals or the sight of a person) to the more heterogeneous (say the albumin of animals or the recognition of a friend with its thousand memories, hopes and fears): that these changes are definitely co-ordinated: and that these changes are all in correspondence with certain phænomena outside the living being. In briefer form he puts it that life is the continual adjustment between external and internal conditions.

The environment of all things non-living or living is liable to change. The non-living thing is passive, at the mercy of its environment, makes no response to its changes. The living thing is active, struggles against the oppression of its surroundings, adapts itself to the changes of the environment. A piece of non-living chalk, were the air surrounding it to be replaced by hydrogen chloride (hydrochloric acid) would be unable to adapt itself to the changed conditions, and would be decomposed with evolution of carbon dioxide. But a living animal under the like circumstances would either rush away from the spot or, if its degree of life were high and it knew Chemistry, would neutralise the acid by ammonia and prevent its ill effect. It would bring about an adjustment between the conditions of its body and those of the environment. Throughout life plant or animal is thus constantly modifying as its surroundings modify. From the first moment of its life to the last the ceaseless changes without are answered by changes within. And those internal changes or changes of the individual are not merely direct and consequential. They are often anticipative. Thus a puppy, beholding its master lay hands on the whip for the first time, eyes him and the whip with a gay and delightsome air of interest. But ere long, the puppy, observing the same change in the environment, not only has certain direct and consequential effects produced on retina and in brain, but anticipative results follow, and he rushes out of the room at the first movement of the hand towards the instrument of punishment. If change A. in the environment is followed by change B. in the plant or animal, change B. is often succeeded by change C. in the living being, this change C. being anticipative of a change D. in the environment that is to follow upon change A.

Further, the degree of life varies with the amount and complexity of this correspondence between the external and internal conditions. The more complete and the more complex the correspondence, the "higher" the life. A plant is lower in the scale of organisation than an animal. Its relationships to the universe outside it are less complex. Only the most general alterations affect it. It is uninfluenced by the special ones. Light, heat, moisture changes have their play upon it. The fluctuations of stock do not disturb its existence. Cold-blooded and warm-blooded animals illustrate the truth. A reptile is, as far as its blood-temperature is concerned, at the mercy of the environment. The temperature of its blood varies with that of the medium wherein it lives. Not so with the mammal. No matter how the air or even the water that is the habitat of the mammal may vary as to temperature, that of the blood of the animal is constant. Thus the temperature of the blood of man in the hottest day in summer or the coldest day in winter is about 36½° C. And the latter animal, having this power of adjustment of its blood-temperature as the outside conditions vary, in higher and more lifeful than the former, the possessor of no such power.

Or to take an illustration from man, the religious person and the Tory are lower in the scale than the Freethinker and the Radical. The former are little affected by the environment. Their relationships thereto are delightfully simple. A simple formula or a simple following carried out doggedly is their sole idea of adjustment to altered external conditions. The formula may be g. o. d. or the following that of Lord Randolph Churchill. That is all one. The formula and the person followed only need to be simple and meaningless and all is well. But with the thinking folk, the changed conditions of the environment affect hugely. Their relationships to thought of all forms are so complex. Touching the world outside them at so many points, the unthinking cannot understand how such as these are influenced by the ceaseless changes of that world without. Those that aim at greater freedom in science, in philosophy, and in politics, have calculations to make that others know not of. Their life is the higher on account of its more complex relationship to the environment. Let them see to it that they make it yet higher by rendering that relationship more complete as well as more complex.

(7) As a contribution to the definitions of life the writer suggests the following. The living plant feeding upon mineral matters, builds up plant matters of greater complexity than the mineral. The living animal feeding on the plant matters builds up animal matters of yet greater complexity. Plant or animal in its life-work decays into mineral matter again. Life, therefore, is functional activity preceded by a building up of more homogeneous structures into more heterogeneous and accompanied by a reduction of the more heterogeneous structures to the more homogeneous again. By "functional activity" it is desired to express that living beings are not passive but are constantly adjusting their own conditions to the varying ones of the environment. I borrow, therefore, the thought of Herbert Spencer and express it by Charles Bradlaugh's convenient phrase "functional activity," while I add the conception of the building up of the carbon dioxide, water, ammonia, and salts of the plant food into the starch, sugar, alkaloids of

the plant — or of the building up of the starch, sugar, and alkaloids of the plant into the albumins and gelatins of the animal, together with the retrograde metamorphosis of the secomplex organic bodies into carbon dioxide, water, and ammonia again as the functional activity is displayed.

During life then this adjustment continues, and this building up and unbuilding succeed one the other. But at length, either by accident or disease, the circumstances of the environment become of such a nature that the adjustment is no longer possible, or the preliminary building up of the simpler into the more complex no longer occurs, as in old age. In either case the being dies. Death is the cessation of the adjustment that has been throughout life or is the cessation of the preliminary up-building. The unbuilding goes on and the body decays into the simpler mineral compounds, without return of the constructive process, and the animal or plant is dead. The body has returned to the mineral kingdom that gave it.

B. *The difference between Plants and Animals.*—Biology is, then, the detailed interpretation of structural and functional phænomena in relation to the phænomena of the environment. Briefly it is the study of living beings. Of these living beings there are two kinds easily enough recognisable and distinguishable from each other in their higher forms. The tree and the quadruped differ widely one from the other. Every one names the former Vegetable, the latter Animal. And these two names are given generally to the two great groups of living things. But whilst it is easy to distinguish between the highly organised members of the two kingdoms, it is impossible to separate them clearly in their lowest forms. A kindred difficulty to that encountered in our effort to separate the living from the non-living meets us when we try to demarcate animals from vegetables. To the evolutionist hard and fast definitions are not possible.

In the old days very clear and exact definitions were given of animals and of vegetables, and unfortunately these are not infrequently repeated to-day. Let us consider the main distinctions that have been stated as existent.

(1) The power of sensation.—Plants were supposed to be destitute of this: animals were supposed to possess such

power. But the response of the leaves of the Sensitive Plant to a touch, of the flower of the Catasetum Orchid to any impression made upon its antennæ, of the suddenly closing leaf of the Venus' Fly-trap to the light contact of the doomed insect, and the effect of light upon plants generally are but a few instances of the widely spread power of responding to stimuli possessed by plants. On the other hand the sensitiveness to stimuli of many living things that are called animals is very low, far lower indeed than is the sensitiveness of many plants. Contrast the power of sensation of an Amœba or of a Sponge with that of a Mimosa or of a Sundew. The vegetables are the more highly endowed of the two.

(2) The power of movement.—Vegetables were supposed not to have power of movement: animals possessed such power. The instances given above serve to dispose of this imaginary distinction as effectually as they do of its predecessor. Each of the plants just named undergoes very remarkable movements of its parts. These movements are complex and co-ordinated. You would be tempted to call them purposeful. The touch upon one of the antennæ of the Catasetum is followed by the liberation of the extraordinary and huge pedicel and disc, and by their outflinging from the strange reptilian flower on to the head of the insect in such fashion that his visit to the next Catasetum must result in the impregnation of the unripe seeds thereof by the pollen borne from its predecessor. Nay, without any known stimulus at all the antennæ undergo movements that place them exactly in the best place to be touched and that afterwards get them out of the way when pollen removal has taken place, and impregnation is to be effected. And if it be urged that the movements in this and in the other plants mentioned are of parts only and not of the individual as a whole, answer is made that there are many animals even high in the scale that only show the like movement of parts with a sedentary condition of the whole organism. The oyster is not active but the cilia or minute hairs on its gills are, and effect ceaseless change of the water in contact with the gills. The sponge, the sea-anemone, the entozoa or internal parasites are all stationary as a whole, though parts are motile. On the other hand many vegetables show at some period of their lives,

and some of them during the whole of their existence, movement of their bodies as a whole. The motile stage of the simple one-celled Protococcus of rain-water, the active zoospores or moving organisms in the Algæ rushing by aid of cilia through the water, the persistent motion from place to place of the Diatoms are all instances of motion in plants affecting the whole of the individual. Movement in plants is then far more general than has been hitherto believed. The latest work of our greatest naturalist is on "The Movements of Plants." From an early copy that the writer owes to the courtesy of Charles Darwin he quotes the following words, with alteration of one technical term: "Apparently every growing part of every plant is continually moving."

(3) The absence of Nitrogen in plants and its presence in animals.—Once on a time the statement was made, that plants had no nitrogen in their composition and consisted in the main of carbon, hydrogen, and oxygen. But plants contain protoplasm, a compound of all four of the above elements. Later the distinction was made that vegetables have no nitrogen in their cell-*wall* and that animals have that element in their cell-wall. As the cell contents of plants contain nitrogen, the distinction at its best would not be of great importance. But whilst the cell-walls of most members of the Vegetabilia consist of cellulose, a compound of carbon, hydrogen, and oxygen $(C^6 H^{10} O^5)^3$, and the cell-walls of most animals are nitrogenous in composition, yet in animals so high in the scale as the Ascidian cellulose is found.

(4) The respiration of plants and animals differs.—It was stated "by them of old time" that whilst animals breathed in oxygen and gave out carbon dioxide, plants breathed in carbon dioxide, retained the carbon, and gave out the oxygen. This purely imaginary distinction was founded upon a misconception. The breathing of plants and animals is identical. Both inspire oxygen and expire carbon dioxide. The effect of their breathing on the air is the same. But plants also feed on the air and in their feeding take in carbon dioxide, retain the carbon and give out oxygen. Their action on the air is twofold and the inspiratory effect is the exact converse of the feeding effect. As the feeding process is with vegetables in excess of the respiratory, the

total effect on the air is the removal of carbon dioxide and the outgiving of oxygen. But to say that plants breathe in carbon dioxide is as inaccurate as to say that a man breathes in carbon dioxide when he drinks champagne.

(5) The different nature of the food.—The food of plants is mineral or inorganic; that of animals is organic. The former feed on gases, water, salts, all of inorganic nature. Carbon dioxide, water, ammonia, salts of the alkaline and alkaline earth metals are the chief food-stuffs. The latter feed on plant-materials directly or indirectly by eating herbivorous animals. But mineral matters enter largely into the food of animals. We drink water and use common salt. And many plants eat organic matters. The Sundew and the Venus' Fly-trap catch and devour insects; the Pitcher-plants and the Bladder-wort feed on dead organic substances.

(6) The in-taking of food by the exterior of plants, by an internal organ in animals.—Plants reach down roots into the soil and lift up leaves into the air. By the surface of root and of leaf food is ingested. Animals take the food into an internal organ called a digestive cavity. But many animals have no such cavity: witness the Amœba and the Tape-worm. And the pitchers of Nepenthes and the bladders of Utricularia are internal food-digesting cavities.

Upon the whole, therefore, no complete distinction is to be drawn between the two great kingdoms of living things. It is not difficult to mark off an oak from a man, but in their lowest forms the plants and animals merge one into the other. So clearly is this the case that Ernest Haeckel has proposed the formation of a group Protista (πρωτος, first) to include those forms of living beings that are not clearly either animal or plant.

Of distinctions obtaining between the higher terms of the series plant and animal those having relation to the nature of the food, and to the composition of the cell-wall, and to the external or internal in-taking of food, would seem to be the best.

C. *Classification.*—For the due comprehension of the papers that will follow this, the succession of the terms used in classifying living beings must be mastered. Those that will be employed by the writer are as follows, and the order of their succession is of great moment to those who desire to grasp the full significance of the illustrations that will be given: Kingdom, Sub-Kingdom, Class, Order, Genus, Species, Variety, Individual. These terms shall be illustrated by reference to a special case—*e. g.*, a dog. Kingdom, Animalia. Sub-Kingdom, Vertebrata. Class, Mammalia. Order, Carnivora. Genus, Canis. Species, Familiaris. Variety, St. Bernard. Individual, Lion.

D. *Divisions of Biology.*—The study of living things is of necessity exceedingly complex. We may consider (1) the names of the different special branches of study that may be classed under the general head of Biological Sciences. This classification is familiar to all students, and need only be called again to their remembrance through the medium of a table:—

BIOLOGY.

Botany, study of plants	Anatomy, study of structure	Histology, study of tissues.
		Morphology, study of organs.
	Physiology, study of function.	
	Classification, study of grouping.	
Zoology, study of animals	Anatomy	Histology.
		Morphology.
	Physiology.	
	Classification.	

(2) The scope of Biology as a whole.—Following the classification of Herbert Spencer we find Biology includes (*a*) the study of structure, (*b*) the study of function, (*c*) the action and reaction of function and structure one upon the other, (*d*) the production of organisms. Let us name these respectively the study of Anatomy, Physiology, Ætiology (*αιτια*, a cause), Genesis (*γενναω*, I produce).

(*a*) Anatomy or the account of structural phænomena subdivides into (i.) The structure of the individual—of the one. (ii.) The structure of the successions of organisms—of the many. And, again, each of these last heads is divisible into (*a*) Morphology, or the account of the adult organism; (β) Embryology, or the account of the development of that organism.

(*b*) Physiology, or the account of functional phænomena, in like manner subdivides into (i.) The functions of the one. (ii.) Those of the many. And again each of these last heads is divisible into (*a*) General Physiology, dealing with all functions of the organism, save that which is dealt with under (β) Psychology. This branch has to do with that special class of functions known as Mental. Both Physiology and Psychology present two further divisions. Thus (*a*) Physiology includes: 1. Organic Chemistry, having to do with the molecular changes occurring in organisms; 2. Organic Physics, treating of the transformation of the forces resulting from chemical changes into other forms of force. (β) Psychology (unfortunately derived from ψύχη, the soul) includes: 1. Objective Psychology, teaching of the functions of the nervous system and motor organs, whereby organisms adjust internal to external relations, and of the external manifestations of those functions in conduct; 2. Subjective Psychology, treating of the sensations, ideas, volitions that are peculiar to the individual organism and accompany the adjustment referred to under 1.

(*c*) Ætiology, the account of the actions and reactions that obtain between structure and function subdivides into: (i.) The account of those occurring in the one. (ii.) The account of those occurring in the many. And of these two groups there are the further sub-divisions: (*a*) Action of function upon structure. (β) Reaction of structure upon function.

(*d*) Genesis, or the account of the phænomena of reproduction, subdivides. (i.) Genesis of individuals. And this falls into two divisions. (*a*) Genesis in the concrete. The enumeration of facts as to reproduction, these facts ranging under the two heads of—1. Asexual reproduction. 2. Sexual reproduction. (β) Genesis in the abstract. The answers to general questions as to the "why" of reproduction rather than the "how": such questions as those dealing with cross-fertilisation in plants. (ii.) Genesis of successions of individuals. This will deal with the highly abstract enquiries into the rate of multiplication of various kinds of organisms.

Arranging these subdivisions of Biology in a tabular form we have :—

BIOLOGY.

(*a*) Anatomy.	i. Of the one	*a* Morphology.	
		β Embryology.	
	ii. Of the many	*a* Morphology.	
		β Embryology.	
(*b*) Physiology.	i. Of the one	*a* General Physiology	1. Organic Chemistry.
			2. Organic Physics.
		β Psychology	1. Objective.
			2. Subjective.
	ii. Of the many	*a* General Physiology	1. Organic Chemistry.
			2. Organic Physics.
		β Psychology	1. Objective.
			2. Subjective.
(*c*) Ætiology.	i. Of the one	*a* Action of function upon structure.	
		β Reaction of structure upon function.	
	ii. Of the many	*a* Action of function upon structure.	
		β Reaction of structure upon function.	
(*d*) Genesis.	i. Of the one	*a* In the concrete	1. Asexual.
			2. Sexual.
		β In the abstract.	
	ii. Of the many		

To render these divisions of Biology yet more intelligible to the student, the attempt will be made to give one illustrative fact under each head :—

(*a*) i. *a*. The heart of man has four cavities.

β. In the development of man the occipital bone ossifies from four centres.

ii. *a*. The members of the class Mammalia have seven neck vertebræ.

β. The members of the class Mammalia in the course of their development form a placenta.

(*b*) i. *a*. 1. A plant decomposes the carbon dioxide of the air, retaining the Carbon, giving out the Oxygen.

2. The protoplasm in the cells of Chara moves.

β. 1. A child moves its hand away from heated metal.
  2. A child is angry at being teased.

ii. α. 1. In wingless insects the chemical transformation of food into wing-moving muscles that occurs in their fellows does not take place.
  2. In the absence of this chemical change the amount of heat given out by such insects is, *cæteris paribus*, less than that given out by their winged fellows.

β. 1. The habits of an ant-colony.
  2. Nothing known yet, as other animals have not hitherto given evidence as to their states of consciousness.

(*c*) i. α. The growth of a blacksmith's arm.

β. The functions of the athlete whose bodily frame is powerful are other than those of the weakly man.

ii. α. Disuse of "wisdom teeth" or last molars in man leading to their imperfect and partially aborted structure.

β. The phænomena of natural selection.

(*d*) i. α. 1. The Hydra gives off many buds similar to the parent.
  2. The pollen grains of an Orchid carried by an insect to the stigma of another kindred Orchid ripen the ovules of the latter.

β. The cause of variation in offspring is difference in the nature and past history of the parents.

ii. The connexion between the birth-rate of a people and the price of corn.

(D) *Biological Terms.*—It is necessary to endeavor to obtain clear conceptions as to certain exceedingly important terms used in Biological Science. Each of these terms will be defined and illustrated.

(1) Function.—The transformation of motion. When we speak of one of the functions of a leaf as that of the formation of green color matter we mean that through the agency of such a leaf the motions of the carbon dioxide, water and ammonia of the air are so modified that there results a new substance chlorophyll (χλωρος, green, φυλλον, a leaf), made of the four elements, carbon, hydrogen, oxygen, nitrogen, and possessed of new and remarkable potential energy.

When we speak of the function of the retina of the eye as sensibility to light, we mean that through certain rod and cone structures in the retina the motions of ether that we name light are transformed into nerve motion in the optic nerve. This last motion in its turn would appear to be transformed into motion in the central organ or brain, ultimating in the consciousness called sight. Of these transformations of motion, called functions in living beings, three great orders present themselves. These are (*a*) Functions of accumulation. Examples of this order are furnished by the functions of digestion and respiration. In the former, food material is transformed and stored up in condition of high potential energy, and in the latter oxygen is dealt with in kindred manner. (*b*) Functions of transference. Examples of this order are furnished by the functions of absorption and circulation. In the former, as it occurs in the higher animals, the digested food is transferred to the blood-system and in the latter the results of digestion are borne into the various regions of the body. (*c*) Functions of expenditure of force. Whilst every function of a living being is attended in its performance with an outlay of force there are certain special transformations of motion that, placing the living thing into the closest relation to its environment, are necessarily functions of expenditure. Examples of this order are furnished by the nervous and the muscular functions. In the former the reception of impressions from without by the sense organs and the transmission thereof to the brain involve expenditure of force. Potential energy becomes kinetic. In the latter the movements of the body involve expenditure of force. We feel that " virtue has gone out of us."

(2) Organ. A special collocation of matter performing a function. The leaf or the eye are arrangements of matter capable of performing certain motion transformations. It may be urged that this definition fails to exclude the galvanic battery and even yet more simple arrangements. A lever or a screw come under this definition. The writer is not greatly concerned even if this be the case, but for Biological investigation the organ will mean a special collection of matter in *a living being* that performs a definite function.

(3) Growth. Increase of mass. Not increase of size necessarily. Growth is increase in actual structure, not simply in

bulk. It may or may not imply increase in dimensions. It must imply increase in the amount of absolute matter in the growing body. The potato of the *Gardiner's Chronicle* that was confined in a dark cellar, although it straggled out in all directions and had finally dimensions far in excess of those orginally possessed by it, did not grow. It weighed less at the end of the experiment than at the beginning. Its mass had diminished. This growth is one of the great causes of the demand for nutrition. It is clearly most noticeable during the earlier stages of the life of the plant or animal—is indeed only encountered during a certain very definite period. Hence is suggested the inquiry, Why is not growth lasting? Why should a living being grow during a certain number of years, or days, or moments, and then cease growing? As growth continues the force-expenditure of the body generally increases more rapidly than the size increases. More and more food supply is therefore needed for the maintenance of force. A drain results upon the food supply needed for growth. At length a time comes when the amount of food supply required for the outgiving of energy is so great that none is available for growth or increase of structure. There is only enough left for the restoration of the parts that are disintegrated in the very act of giving out energy. This much must be secured or bodily decay as a whole sets in and death ensues, but more than this is not forthcoming in consequence of the large quantity demanded by the organs whose function is force-expenditure. The plant or animal is full grown.

(4) Differentiation.—The passage of matter from the relatively homogeneous to the relatively heterogeneous. Here is something more than mere growth. There is not only increase in matter as far as quantity is concerned. There is also a change of its quality. The nearly homogeneous piece of protoplasm not only grows, but its exterior is transformed into a cellulose wall in the differentiating plant. Into the simple matrix of the cartilage shoot out bone structures in the animal. Every part of the most complex body is to be formed out of a single cell supplied with certain materials from without. Clearly there must be no small transformation of the matter of the cell and of its food supply ere manifold organs can result. That transformation is differentiation. In all its stages this differentiation is a

passage from simpler to more complex. Only in its very earliest stages is the passage from the homogeneous into the heterogeneous. Later on it is the transformation of matter which is comparatively simple into that which is less simple. This is seen in the example just given. The partially differentiated cartilage passes into the yet more highly differentiated bone.

(5) Development. Growth + differentiation.—In the passage of plant or animal from its embryonic condition on towards its adult condition the plant or animal grows or increases in structure. It also differentiates or passes from more homogeneous condition to more heterogeneous. Out of the microscopic simple cell is gradually formed the huge tree with roots, and stem, and leaf, and flower, each whereof is further made up of many tissues differing one from the other. Out of the microscopic simple cell is gradually formed the majestic animal with manifold organs built up of complex tissues. And this passage from the primal simple state through many stages of growth and of differentiation to the full grown and completely differentiated adult condition is the *development* of the living being.

(6) Adaptation.—The response to the alterations of the environment. Necessarily, from our very definition of life we must admit that this adaptation occurs every moment of life. The adjustment of internal to external conditions is adaptation. The student who finds himself amongst a number of boating and cricket men in the smoking room talks boating and cricket. He adapts himself, if he be wise and lifeful, to his company. The word adaptation is however generally confined to those momentous responses to the changed conditions of the environment that produce permanent, noticeable changes in function and in structure. Thus the seal, of the order Carnivora, of the class Mammalia, has, in the course of its evolution, from some form common to it and other flesh-eating animals, undergone considerable changes that have resulted in its present structure so excellently adapted to living in water.

The changes implied in this adaptation are very slight at first. They are so slight as to be well-nigh imperceptible. It is only after they have continued through many generations that they have accumulated enough to be plainly recognised. For it must be remembered that the slight change that is adaptation in the individual is transmitted to the offspring in intensified form, and to their offspring in form yet more marked, if the change be of such a nature as to give its possessor an advantage in the struggle for life. It has been written that "adaptation is striven after by the individual, transmitted to the offspring, and developed by natural selection;" and this phrase puts the truth very clearly with, to the present writer, the exception of the phrase "striven after." This expression seems to him an unfortunate one, as implying too much activity, an activity of a voluntary nature, in the plant or animal in its response to the changed conditions of the environment.

In adaptation, function change appears to precede change of structure. It has long been a question whether function was the cause or the consequence of organisation. The study of living things in the light of the fact of evolution reveals to us that function is more probably the precursor than the successor of organisation. In evolution function change seems ever to precede structural modification. Thus, in the human heart, the structure of the muscles contained in that organ is that of voluntary muscle, or muscle under the control of the will. But the heart-muscles functionally are involuntary, not under the control of the will. The structure has not changed. The function of the muscles is altered, and with good result to the animal, as it is of distinct advantage to have the management of the contractions of the heart removed from the category of the voluntary actions. Or consider the feet-jaws or maxillipedes of the lobster (class Crustacea). Structurally, they are built upon the model of the next of the body appendages to them, the legs. But as their name tells, they are not alone mobile. They help in mastication also, and are feet-jaws. Their function has changed before their structure has.

This principle of adaptation further helps us to understand the development of more highly-functioned organs out of organs of simpler functions. It aids us in the comprehension of the gradual evolution of complex organs. The lung of the air-breathing vertebrate has been evolved from the swim-bladder of the fish. Not suddenly. Nature does not work her best work in cataclysms. Slowly, in certain individuals in the remote past, the bladder that had only served to regulate the specific gravity of the fish, and to enable it to sink or to rise in the water by the diminution or the increase in its contained air, began to absorb the oxygen of that air, to give thereto carbon dioxide. With the growth of this respiratory process the animal became better fitted for longer sojourn outside the water. Upon the change of function followed that of structure, and by degrees, the old use of the organ fading away, the old structure also was modified and modified, and the swim-bladder developed into a lung.

Finally, let it be noted that adaptation is the radical principle in evolution. It is the principle of alteration for the better. Later we shall encounter a conservative principle—the only righteous conservative principle, that endeavors to maintain and perpetuate the change until such time as another alteration is wisdom.

(7) Variability.—Capacity for adaptation. It is the ability to vary—*i.e.*, to adapt. Variation is, in all probability, the same as adaptation. "Spontaneous" variation, on the part of a living being, does not seem to be conceivable. The variations so constantly occurring are caused. Their cause would appear to be the ever-changing conditions of the environment. Variability, in the strict sense of capacity for adaptation, is the great characteristic of living things, is inherent in them.

(8) Transmission.—The appearance in the offspring of changes of structure or function that have taken place in ancestral beings. This is the conservative principle to which reference was made. Without it evolution would be impossible. If every change that was for the advantage of the individual died out with the life of the individual, the universe would be an eternal beginning over again. But the adaptation "striven after" by the one is transmitted to the offspring and becomes intensified. Transmission is often named heredity. I am inclined to restrict this word to the transmission of individual peculiarities, and to keep the more general name for the transmission of characters that belong to the variety, the species and to all the higher grades. Heirship is so essentially the inheritance from man to man, and it seems so desirable to distinguish between the reappearance of individual specialties and the reappearance of properties of the race, that I venture to suggest the use of the two names Heredity and Transmission to denote these twain.

In connexion with this subject, it is important to notice that there is that which may be called a sexual transmission. Whilst the natures of both parents affect all the offspring, there is reason to believe that the nature of the parent of one sex affects especially the children of the same sex. Hence the mental calibre of the majority of our women to-day, their conservatism, their religion, their conventionality, their want of comprehension of the beauty of the keen intellectual life all a-glow with deep contained emotion, are due to the evil treatment of their mothers and grandmothers at the hands of man in the past.

(9) Atavism.—Reversion to ancestral forms. The horse is born with certain stripe-markings, which would seem to be somewhat of a work of supererogation on the part of nature, as in this most Christian country stripe-markings upon horses are many enough after birth. These lines of color are reversions to an ancestral form, probably common to the horse and the zebra. Any one of the numerous varieties of pigeon may lay an egg whence emerges not a tumbler or a fantail, but a blue rock. Now, the blue rock is the parent of all the other varieties. This is a case of reversion to ancestral forms or of atavism.

(10) Correlation.—Interdependence of structures. Modifications of particular parts of a living body affect other parts. Changes in the nature of hard external parts will cause changes in the nature of soft internal ones. The excessive elongation of the snake's body is attended with a like elongation of certain organs, as its lung. The integuments of the whale (Cetacea) and of the Armadillo (Edentata) are strangely different from those of other Mammalia, and their teeth also differ from those of other Mammalia.

(11) Rhythm.—Oscillation of motion or alternation of opposites. Movement, in any one direction, is always followed by movement in the contrary direction. This principle of rhythm is an inevitable corollary from the persistence of force, from the eternal nature of matter and of motion. Were it not true, creation of motion would be possible. The third law of motion in Physics states that action and reaction are equal and opposite. The magnetic needle at this hour does not point due north. It points some 17° west of the north pole. But last year its position was different, and in 1882 its position will be different from that of to-day. It is

slowly swinging eastwards. In 1657 it did point due north, after struggling through the centuries from a position wherein it pointed far away to the east of the pole. From 1657 to 1818 it swung slowly westward. Then it began to retrace its steps, and since then it has traversed nearly 5° on its path towards the sun-rise. Day follows night, summer treads on the heels of winter. In history, the epoch of Puritanism is succeeded by the Court of Charles II., and in the days when kings were kings the weak monarchs alternated strangely with the strong. Henry III., Edward I., Edward II., Edward III., Richard II., Henry IV.—these names will serve as illustration. In politics, a time of suspicion, uneasiness, untruth, wrong, degradation of a nation's name and honor, is followed by a time of healthful, honest striving, through many difficulties, to do the right and to keep faith with all. Tory governments are succeeded by Liberal ones, and with the terrific irony of the universe, Liberal governments are doomed to be, in their turn, displaced. In our own lives joy follows sorrow, and sorrow follows joy, with rhythmical regularity. Laughter melts into tears and through our tears we smile. But yesterday the world was a desert wide-reaching, sombre. To-day it is sunlit, odor-breathing; and to-morrow the waste will lie before our feet again.

CHAPTER VI.

MORPHOLOGY.

THE study of the structure of living beings will engage our attention next. In a volume such as this only the most general points in structure can be dealt with. We shall consider (A.) the units of structure, (B.) the successions of structural forms, (C.) Crystalloids and Colloids, (D.) Homology.

A. *The Units of Structure.*—All plants and animals are reducible to certain simple constituents. Every plant and animal consists of organs, such as the leaf and root, or the hand and brain. These organs are again constructed of yet simpler parts, such as the epidermis and veins of the leaf, or the muscles and nerves of the hand. Such simpler constituents of the organs are called tissues. But these tissues again consist of still simpler parts. The epidermis of the plant is made up of cells, the veins of the leaf are made up of fibres and vessels, the muscles and nerves of the hand are in like fashion made of fibres, but of fibres of different nature from those met with in vegetables. The ultimate constituents are few; the tissues and organs made out of them are almost infinite in their number and variety, in the same fashion as the letters of the alphabet are few in number, but the combinations of them into words practically innumerable. Cells, fibres, vessels constitute, in the main, all plant or animal tissues. (1) The cell may be defined as a limiting membrane bounding certain contents. In its simplest or in its most complex form the cell will always present certain materials surrounded by a definite wall. (2) The fibre is an elongated structure, in plants generally resulting from the elongation of one cell. In animal structures more than one cell may enter into its composition. In either case it is a structure, as in muscular fibre, or as in wood fibre, whose length in one direction considerably exceeds that in any other. (3) The vessel is a long tube, formed probably invariably from the fusion together of many cells. Imagine a number of cells placed end to end, their cavities separated by partitions. If the partitions disappear and the cavities of the cells enter into communication a long tube or vessel will result.

The cell, the fibre, and the vessel then constitute the units of tissues, and as the fibre and the vessel are both formed out of the cell the cell might be looked upon as the ultimate unit. Indeed until recently it was regarded in this light. The celebrated theory of Virchow, the cellular theory, taught this doctrine, that the cell was the ultimate unit of structure, and that out of it all tissues were formed. Indeed, the cell was the material form absolutely necessary for life, and inasmuch as the cell was very considerably different from any inorganic structure it was more than hinted at that the difference between living and non-living things was enormous, even when only structure was taken into consideration. So long as the cell was regarded in this light, and all living matter was supposed to have no simpler form than the cell, without doubt great difficulty presented itself to the evolutionist. To bridge over the distance between inorganic matter and the cell was difficult, if not impossible. But further investigation has placed the evolutionist in a better position, as investigation always does. Scarcely anyone would be found today to support the doctrine that the cell is the simplest condition of living matter. Better microscopes, more numerous observers, and more accurate observers have revealed to us that there are structures far simpler than the cell that are clearly living. Let us consider those structures.

The cell, it has been stated, is a limiting membrane enclosing certain contents. The nature of the membrane varies in plants and animals; the nature of the contents, at least in young cells, is invariable. The contents are protoplasm. Of this exceedingly important structure the following statements may be made. It consists of carbon, hydrogen, oxygen, and nitrogen. It is contractile. Under favorable circumstances it will develop into more highly organised substance.

In the cell is generally to be seen a portion of protoplasm more condensed than the rest. This is known as the nucleus.

or endoplast, and hence the typical cell presents a wall, varying in its nature in plant and animal, containing protoplasm and an endoplast. This assuredly is a complex structure, more complex than aught presented by the mineral kingdom. But living organisms have been met with of simpler build than this. For example, the cell is encountered destitute of its endoplast, that is, only presenting wall and protoplasm. Low down in the plant and animal kingdom are many beings consisting wholly of wall and protoplasm. Such structures are sufficiently distinct from the cell to deserve a special name. Hence the name cytod has been devised. (4) A cytod, therefore, is a mass of protoplasm surrounded by a limiting membrane, but containing no specially condensed part called endoplast. If research had not discovered amongst living things structures simpler than this, the difficulty for the evolutionist would still be great. But research has shown us that there are living bodies of yet simpler structure. Imagine the cytod loosened from its limiting membrane. Imagine it reduced to the condition of simple protoplasm. It is now a mass of protoplasm without any wall investing it. In that condition it is still living matter. It is seen to move. It is seen to reproduce itself. It lives, it moves, it has its being. To this mass of protoplasm not surrounded by any definite wall the name of plastid is given. That is as far as research has carried us hitherto. But observe how very much simpler is this plastid than the cell that but a few years ago was proclaimed as the unit of structure of living beings. Whether we shall ever discover still simpler structures than the plastid remains to be seen, but whether we discover them or not, the distance between a simple, unenclosed, exceedingly minute mass of protoplasm and a piece of mineral matter is exceedingly small. Later on we shall have to discuss the possibility of the formation of protoplasm from inorganic matter. For the present, it is sufficient to say that the plastid is our morphological ultimate unit, and is the simplest form of structure known to us in connexion with living beings.

B. *Successions of structural forms.*—Now it will be wise to ascend from this plastid to the higher morphological conditions. Given this portion of unenclosed protoplasm as living matter, it will be well to picture how it and its fellows and their higher derivatives are grouped together in making plants and animals. Some living beings consist solely of unenclosed protoplasm. An example of these would be Æthalium, one of the lowest Fungi. Slow-moving masses of protoplasm, sometimes of considerable size, are observed creeping lethargically over stones, and even over pieces of metal. The Bacteria that crowd together in millions in liquids containing decaying organic matter are plastids also. Ascending a little higher, the cytod meets us. The Yeast fungus consists of nothing but multitudinous individuals each of which is a cytod, that is, a mass of protoplasm surrounded by a wall, without endoplast. In the animal kingdom we encounter some of the Foraminifera. These wonderful little organisms, whose tiny shells, shaped in the most diversely fantastic form, have been ceaselessly raining down through the sea, fathom after fathom, and generation after generation, whose shells have formed the base of the ocean and the substance of continents, each of these imperturbable little workers, lodged within its diaphanous casement, is a cytod, and nothing more. Passing still higher, the plant or the animal is a cell. The cytod has now gained its endoplast. Amongst vegetables the majority of the lower Algæ, or water-dwellers, are of this type. Amongst animals the Infusoria, whose movements are complex functions many, are nevertheless only single cells. In fact in the lowest sub-kingdom of animals, the Protozoa, nothing higher than the cell is to be seen. The lowest of its members are plastids, the next lowest are cytods, but the highest of this large sub-kingdom never pass beyond the stage of the single cell. If we pass upwards through the plant and the animal kingdom we shall find beings composed of many cells that, at first, are still of the simple order, as in the Volvox or the Sphærozoum. But very speedily the collections of simple cells become collections of modified cells. Certain cells elongate and become fibres, certain others fuse one with another and become vessels. The fibres vary in their nature. The vessels vary in theirs. Groups of cells, fibres, vessels, separate themselves in position, as in function, from certain other groups, and tissues appear on the scene. Some tissues are purely cellular, as the pith of the tree. Others consist of cells but slightly modified, as the epidermis of a plant or animal. Others present far greater complexity, as the complex nervous tissue of an animal. These tissues group themselves into organs. The stamen, or the hand, is but a collection of tissues. The organs become grouped into organisms. The oak-tree or the man is but a collection of organs.

c. *Crystalloids and Colloids.*—Dealing, in the last paragraph, with the units of structure, nothing was said in respect to the chemical and physical nature of their constituents. It is now necessary to consider the general principles of the difference in chemical and physical nature between inorganic and organic bodies. To understand this, the distinction between crystalloids and colloids must be pointed out. Crystalloid bodies are represented by common salt, NaCl, the arsenic of ordinary language, really an oxide of the metal arsenic, As^2O^3, sulphate of iron, $Fe SO^4$. Colloids (from κολλη, glue), are represented by gelatine, albumen, starch. The former are soluble in water, their solutions are sapid or possess taste, and readily pass through a porous membrane. This passage of fluids through a porous membrane is called osmosis. On the other hand, colloids are not readily soluble; even if their solutions are formed, they possess little or no taste, and they will not osmose readily—that is, they will not pass readily through a porous membrane.

Crystalloid bodies, with their solubility, their taste and their osmotic power, are common enough in the mineral kingdom. The insoluble, tasteless, non-osmosable colloids are encountered in the plant and animal kingdoms. They are exceedingly inert, and yet exceptionally unstable. They are inert, and possess, therefore, little power of liberating energy, unless acted upon by external forces. They are unstable, and, therefore, are likely to be easily acted upon by extraneous forces, and made to liberate energy. Thus they realise the two things to be desired in living bodies. These are mechanical fixity and rapid escape of waste products. Mechanical fixity is afforded by the complex compounds consisting of vast atoms and possessing great inertia that enter into the composition of organised bodies. As result of the working of these colloid bodies under the influence of external forces, large stores of energy are liberated, and waste products, in the form of carbonic acid, water and ammonia, are formed. These three products of the working of the tissues are highly mobile, and hence their necessary escape from the body is rapid.

The crystalloid and colloid conditions of matter, appearing respectively in the inorganic and the organic groups, have been called statical and dynamical conditions, and the terms are of value if the one imply that the crystalloid condition is one not readily changed under the incidence of external forces, and the other that the colloid condition does readily undergo transformation under such incidence.

D. *Homology*, from ὁμοιος, like, λογος, science. Likeness in Structure. Amongst morphological facts, few are more interesting to the evolutionist than those referring to homology. The kinship in structure between organs met with in different animals, and often apparently very different in nature one from the other, the discovery of such kinships, and the linking together of structures that seem to be wide as the poles asunder, by the observation of multitudinous intermediate structures, are branches of biological study as interesting as they are important. The key to very much in evolution is to be found in the proper study of homology, or likeness in structure. A few typical instances of homologous structures will be given.

(1) The spore cases of ferns and plant hairs. The little brown patches that are seen on the backs of the leaves of ferns are collections of minute cases containing spores. The spores are still more minute structures that will help, under favorable circumstances, to ultimately reproduce the fern. Each of these little cases contains many spores, is made of many cells, is generally provided with a curious elastic ring, whose contraction serves to rupture it and to liberate the spores. Yet, complex as are these spore-cases, the history of their development shows that they are but modified hairs. That which in other plants, and in other parts of the same plant, becomes simply an extension of the epidermis, in the ferns becomes, when formed on the back of its leaves, a remarkable spore-case with its remarkable contents. Nay this homology may be carried much further than this, for extensions of the epidermis of plants, whether they be simply hairs, or scales, or stinging apparatus, or secreting glands, or spore-cases, or bristles or prickles, or even, in some cases, reproductive organs, are regarded as having a community of structure. They are all homologues one of the other, and are all included under the wide-reaching name of Trichomes, from θριξ, a hair.

(2) The leaves and the flower organs. All the parts of an ordinary flower are metamorphosed leaves. The green outer sepals, the brightly-colored petals, the threadlike stamens with pollen-laden heads, and the green carpels with their contained unripe seeds, each and all are homologues of the leaf. That this is the case is shown (*a*) by the transition forms that are met with connecting together leaves, bracts, sepals, petals, and stamens; (*b*) by the structure of the parts of the flower being largely identical with that of the leaf; (*c*) by the history of the development of the floral organs from structures that in the early stages are indistinguishable from leaves; (*d*) by the reversion in certain cases of parts or of the whole of a flower to the condition of leaves. The parts of the flower are therefore homologues of leaves, and the flower itself a homologue of a branch.

(3) The upper and lower extremities in man. Diverse as their functions are, the upper and lower extremities in the human being are built on similar lines. The arch that supports the upper has its homologue in the arch that supports the lower. The scapula, or blade-bone, and clavicle, or collar-bone, represent, and are represented by ossa innominata, or hip-bones. The scapula and clavicle make the arch that supports the upper limb: the ossa innominata constitute the major part of the pelvis or bony basin into whose sides the highest bones of the lower limb are fixed. The humerus, or the bone that extends from the shoulder to the elbow, corresponds with the femur, or the bone that extends from the hip to the knee. The two bones of the fore-arm, the radius on the thumb side and the ulna on the little-finger side, correspond with the two bones of the leg, the tibia on the big-toe side, and the fibula on the little-toe side. The carpus or wrist with its eight bones represents the tarsus or ancle with its seven, one of which really consists of two. The five meta-carpal in the palm of the hand, and meta-tarsal in the sole of the foot are alike, and each hand and each foot possesses fourteen phalanges or bones of the digits. Further, every muscle in the arm has its representative in the leg. The distribution of the blood-vessels and the nerves in the two limbs is the same. Here then is a striking instance of homology. The upper and the lower limbs are strikingly alike in

structure, but are clearly very unlike in the functions that they respectively perform.

(4) The swim-bladder of the fish and the lung of the man. It has been already shown that the lung of air breathing Vertebrata is probably an evolution from the swim-bladder of the water-dwelling Vertebrata. The history of the development of the two, the position of the two organs in their respective body-cavities, the study of many intermediate forms, all point to the fact that the structural natures of these organs so widely different in their functions are one. Here again is homology without any similarity of function.

CHAPTER VII.

PHYSIOLOGY.

SOME of the most general facts and principles in connexion with Physiology will now be studied. Physiology is the study of the functions of living beings, and function, it is to be remembered, is the transformation of motion.

Under this head we shall study: (A) Waste and Repair, (B) Physiological Units, (C) Function Curves, (D) Analogy, (E) Von Baer's Law.

A. *Waste and Repair.* Whether an organ of a plant or animal is performing its function or is quiescent, waste must occur. A mere piece of iron exposed to the air and acted upon by its environment wastes away, and a perfectly still muscle, or a perfectly unused brain, the conception of which is not difficult, nevertheless are constantly undergoing slow decay. Necessarily, when the organs are at work the extent of that decay is increased. When the muscle works or the brain thinks the matter of muscle or of brain undergoes large disintegration, but it is of the most vital importance to bear in mind that every tissue of every organ of every living being must undergo the inevitable waste due to its very existence. It may undergo the decay due to its performance of the function that constitutes it part of the organ.

When food is taken into a living organism, force is exerted upon it. The force of the swallowing muscles, the force of those present in the walls of the stomach and the intestine, the force due to the high temperature of the alimentary canal, the force due to the action upon that food of the secretions from salivary glands, gastric glands, intestinal glands, liver and pancreas all come into play. From the moment that the piece of food enters into the body until its digestion is complete, energy is being devoted to it. Nay, after its digestion is complete, and it is being absorbed by the lacteals of the intestine, carried by them to the blood, by the blood to the body generally, and stored up in the various organs of the body, during the whole of this time energy is being exerted upon it. As result of all this force working upon the food, we have that food transformed, say, into a portion of muscle or into a portion of nerve. It is now in a state of high potential energy—a state of unstable equilibrium. If the organ of which it formed part does no work, yet this transformed piece of food slowly decays into carbonic acid, water, and ammonia. If the organ whereof it forms part does work, the transformation is but the more sudden. Even if the body of which it formed part die, the transformation into carbonic acid, water, and ammonia of that portion of the dead body into which this particular piece of food has been converted is identical, in nature and amount, with the transformation that would have occurred had the living organ remained quiescent, performing no function. And just as much power is given out, or, in more technical language, just as much potential energy becomes kinetic, when the transformed piece of food returns to the simpler condition of carbonic acid, water, and ammonia, as was exerted by the living body upon that food in changing it into body matter. Throughout the whole of this process there is no loophole for the admission of any special vital force. The amounts of motion expended in the one direction and in the other are identical. The endowment of the part of the living body constructed out of the food with a special "vital" capacity involves the creation of motion.

Each portion of energy exerted by an organism implies, therefore, to us the transformation of as much organic matter as contained that energy in a latent or potential condition. Whilst one of the characteristics of living beings is, then, to raise simpler matter (such as the constituents of the food) to a more complex condition, and, again, in the very performance of life-functions, to reduce the more complex to the simpler, whilst life involves constant waste, and, therefore, constant repair, it should be noticed that, the lower the life, the less the waste and the less the repair. Compare the existence of a tree with that of an animal. There is waste and there is repair in the tree, but the amount of both in a given time is far inferior to that encountered in animals, even low down in the scale. Or compare, again, such an animal as an oyster with a fish. The amount of waste in the oyster's body is, palpably, far less than that in the fish. As palpably is the amount of waste in the fish's body less than that in the mammal's. The low creatures live slowly. The high creatures live active, energetic lives, wherein there is much waste of the rightful order, much constant repair. Hence substitution of the better for the worse, hence constant change. The dull, stagnant life, that is existence rather than life, is unknown to the lofty ones. Ceaseless change, constant alteration of the environment, and all that which responds to it, infinity of relationships to those outside us, the touch of the world at so many points that the life becomes rounded and complete, these are the characteristics of the higher life.

Yet further, for special waste there must be special repair. If a particular organ is employed in excess, the decay of its special tissues will be in excess, and there will be demand upon the nutritive fluid for a special supply of the materials constituting them. The cricket-player, at the end of a hard day's leather-hunting, has made special demands upon his muscles; special waste of those muscles has taken place. For the purpose of their recuperation it will be necessary that he take food rich in the nitrogenous matters essential to the re-formation of muscle. The student during a long day has been poring over the universal comforters called books; special demands have been made upon his nervous structures and there has been of these special waste. He, in his, turn, taking food, withdraws from that food the special matters, rich in phosphorus, necessary for the repair of nerve-structure.

B. *Physiological Units.* How is this repair dealt with in the preceding paragraphs effected? Part of the body has been hard at work. It is exhausted. Its tissue has been in large measure disintegrated. What is the method of its restoration? The fresh, lifeful, arterial blood comes coursing through the organ. That blood is rich with a thousand matters. Out of these the worked-out tissues select such as are of avail to them. The muscle does not select what is only of value to the nerve; the nerve rejects materials that are only necessary for the muscle. Each organ out of the multitudinous constituents of the blood takes its own. Certain units out of myriads are removed by each part, and, yet more mysterious, the units of the tissues are not the same as those of the blood. Dissolved in the blood is encountered nothing that could by possibility be called muscular or nervous or connective tissue, yet the necessary atoms are selected and are transformed into muscular or nervous or connective tissue. This power is not resident in *chemical* units, for the chemical constitution of the tissues of all animals is practically the same. From the lowest to the highest the chemical units are reducible to proteids. Yet, consider the infinite diversity of animals. Or, taking the case of one animal, its various tissues have a like chemical constitution ultimately, though their nature and their functions differ widely. Reduced to their proximate compounds, the same chemical substances are found running through all. Clearly this power of special selection of special things by special organs cannot be resident in chemical units. Again, it is impossible to conceive it as resident in *morphological* units, even if the morphological unit be regarded as a cell. The cell is not universal in completely-formed and active tissues. Consider for a moment the restoration occurring in a healing wound. A fluid is poured out from the blood over the surface of the wound, a fluid that contains no trace of the cells, or fibres, or vessels that are necessary for the restoration of the destroyed structure. The surface and boundaries of the wound do not necessarily contain the same structures as those that are to be re-formed, and yet, out of that fluid poured out from the blood, skin, blood-vessels, nerves, lymphatics, connective tissue, even bone itself, will be formed. It is difficult, therefore, to assign this power of selection to either chemical or morphological units. Hence the convenient, and probably accurate, hypothesis of *physiological* units made of chemical units, and having the power of selecting from the nutritive fluid the requisite materials for the repair of tissues. They even possess the power of influencing the form of the aggregate that they are building up piece by piece. A child is born with a bifid thumb. One of the divisions is removed by amputation. It is well-known that there is great likelihood of that division growing again. In that case we conceive of physiological units selecting from the blood certain materials, and slowly building up the form of the removed part once more. That will be an illustration of what is meant by these units not only selecting special materials but influencing the form of the aggregate that is to be constructed. Lastly, we are bound to conceive of these as distinct from one another in different beings. The lobster whose claw is removed builds up another claw. The salamander whose leg is amputated builds up another leg. The man whose nail is extracted forms another nail. And hence we are entitled to believe that in these three, and in other living beings, and in different parts of the same being, the physiological units differ in their nature, select different materials from the blood, build up different structures.

C. *Function-curves.*—Living beings perform their various functions with varying degrees of energy at different times. The amounts of muscular force put forth by a baby, a child, a boy, a youth, a grown, a middle-aged, an old man, a nonagenarian, differ enormously in quantity. Each function is at first exercised in very slight degree, increases gradually in extent, reaches a maximum, declines, and is ultimately no longer performed. Subject to minor, secondary fluctuations, the amount of the function steadily increases until the maximum is reached, and then steadily decreases. Following a simple mathematical method, let us mark off along a horizontal line a series of equal lengths to represent equal periods of time during which some special function—say, *e.g.*, the formation of green color matter by a plant or the performance of muscular movement by an animal—is occurring. At the extremity of each of these equal lines measured in the horizontal direction let us draw vertical lines whose lengths shall represent the intensity of the function at the particular time. We shall thus have a horizontal line made up of very numerous equal small pieces representing the time and the divisions of the time during which the particular function is performed. We shall have also a series of vertical lines of different lengths representing the degree or intensity or amount of the function at different periods. If a line be now drawn connecting the summits of the vertical lines, this new line will be a curve, first ascending, and then descending, and may be called a function-curve. The closely accurate construction of such function-curves has yet to be carried out, but the general fact that they can be formed is assured. As the tide steadily rises to its full height and then steadily falls while there are the secondary ebbs and flows of successive waves, so any function of a living being, whilst there may be diurnal or even hourly secondary increase and diminution, yet in the main rises to its maximum, and falls away again to nothing.

Such curves are constructable in relation to other elements than time. Thus the performance of any particular function is closely connected with temperature. Probably every organ-action of every living being has a definite range of temperature within which it can occur and outside the limits of which that particular organ-action is not possible. There is a lower and an upper limit. Consider the function of germination in wheat. Below the temperature of 5° C. germination cannot occur, as far as present observations go. Above the temperature of 38° C. germination cannot take place, as far as present observations go. Between these two limits wheat-seeds, certain other necessary conditions being fulfilled, will grow. Again as the temperature to which the seeds are exposed rises from the lower of these two limits towards the upper the activity of the seed-growth increases, until a certain intermediate temperature is reached whereat germination is at its maximum. At temperatures between this special one and the higher limit, less and less is the energy of the process. In short, if we mark off again along a horizontal line equal lengths to represent degrees or fractions of a degree of temperature and draw at the extremities of these equal lengths vertical lines whose lengths represent the intensity of the function at the given times and if the successive summits of these vertical lines be joined we shall have an ascending and descending curve again. This might be called the function-curve in relation to temperature as the former one was the function-curve in relation to time. When curves of like nature to these have been built up for the different functions of plants and animals in relation to time, temperature, electricity, light, hygrometric conditions, age, sex, bulk, and so forth there will the possibility of a much clearer insight into the connexion between life phænomena and so-called physical agencies.

D. *Analogy.*—Whilst dealing with morphology, we had occasion to discuss homology, or likeness in structure. Now that physiology is our subject of study, we encounter analogy. This is likeness in function. Parts of organisms are analogous when they perform similar actions, but are not necessarily connected with each other by any community of origin or of anatomical nature. As instances of analogy, let us consider the following.

(1.) The antherozoids of ferns and the pollen-grains of a rose. The spores on the back of fern-leaves are only of the nature of buds. They are not sexual. When they fall into suitable earth, under suitable conditions, they grow up, not into a fern like that whence they came, but into a small green cellular expansion. In this are formed true reproducing organs, very minute and not easy of discovery. Hence, indeed, the name of the great sub-kingdom of plants to which the fern belongs. It is the sub-kingdom Cryptogamia, from κρυπτος, hidden, γαμος, marriage. Within the male organ are developed very minute oddly-shaped bodies, provided with cilia, or fine hairs, by the aid of whose vibratile motion these antherozoids move about actively, and ultimately may reach and impregnate the female cell. In the flower of the rose are the yellow stamens, with their anther caps rich in pollen. Each grain of this pollen-dust is a complex cell, with highly-organised contents. It may be borne by wind or insect to the female portion of a flower kindred to that whence it came, and, growing down the style into the seed-case below, ultimately impregnate the female cell. Here, then, are two structures, the antherozoid of the fern and the pollen-cell of the flowering-plant, dissimilar in origin, in development, in structure, but performing the same function, that of fertilisation of the female cell. They are not homologous. They are analogous. Indeed, in this case the analogy may be stretched yet further without strain. These fertilising structures are analogues of the spermatozoids of animals.

(2) The gills of a fish and the lungs of a man. The gills of the fish are developed upon certain arches connected with the pharynx of the animal. Man has a representative of those gill-bearing arches in certain portions of the hyoid bone that exists in the neck and supports the tongue. It carries nothing to represent gills. But whilst the horns or cornua of the hyoid are homologues of the gill-carrying arches, and whilst no exact homologue of the gill is borne by them, the lungs of the man perform the same office as that belonging to the gills of the fish. Lungs and gills are breathing apparatus. They both serve for introduction of oxygen into

the blood, and for elimination of carbon dioxide from the blood. Their respective positions in the body, their connexions, developments and structure differ. They are not homologous. But they both perform the same function: they are both respiratory organs. They are analogous. And this analogy may be carried yet further, also without strain. For the lungs of the higher Vertebrata are not only analogues of the gills of Pisces, but are analogues of the tracheæ or air-tubes of Insecta, of the gills of Crustacea and Mollusca, of the pseud-hæmal vessels of the Earthworm, the water-vascular system of the Tape-worm, the contractile vesicles of the Infusoria, and the general surface of the plant. All of these parts so different in structure perform a like function. All are respiratory. Each is an analogue of all the rest.

E. *Von Baer's Law.*—Von Baer, a German, born in 1792, and Professor of Zoology at Königsberg—of whom it has been written that he has touched nothing upon which he has not thrown a flood of light—amongst other important generalisations in biological science, enunciated the principle known to-day by his name. Accurately and fully stated this generalisation runs thus: that in the lower animals all parts of the body perform indifferently all functions, but that as we ascend in the animal kingdom special parts are set aside for special functions. Briefly, it is the principle of the progress from the general to the special, and it goes hand in hand with the idea involved in the phrase of Milne-Edwards, "the physiological division of labor." In the lowest plants and animals every part of the organism performs every function. No special organs or even special regions are devoted to particular functions. In the single cell of the Yeast Fungus or in the plastid called Amœba every part does everything. The body functions are not yet divided amongst different organs. But as we pass from lowest to higher, and on towards the highest, following in the footsteps of evolution, we meet with advancing specialisation. Regions of the body at first take on separate functions. Gradually, the regions become more and more specialised, and what was only a region becomes an organ. In place of the performance of functions in the lowly-organised beings indifferently, in both senses, by any part of the body, we find special organs performing special functions far more thoroughly; and the higher we ascend the more complete is the specialisation, the more thorough the physiological division of labor, the greater the number of organs performing particular functions, and the more thorough the performance of those functions.

To illustrate this principle, let us consider one special function in the light of this luminous generalisation. We will select that of Digestion, and confine our attention to its evolution from the simple to the complex in the animal kingdom only.

(1) Gregarina.—The Gregarine is a lowly-organised creature, infesting the cockroach especially. It takes in by the whole surface of its body food already prepared for it by the animal within which it lives. Lying inert within the intestine of its host, the Gregarine receives food already digested, ingests it by all or by any part of its exterior, and probably exerts upon it but little action.

(2) Amœba.—Here, again, the general surface is the mouth. At any part the food can be taken in. But there are advances upon the condition of things met with in the Gregarine. The food of the Amœba is not food that has been previously digested. It lives in water, not in the interior of another animal. Again, the Amœba puts out processes of its body to seize its food. From any part of its organisation extensions can be protruded that, moving towards the food-particle, seize upon and draw it into the substance of the animal. The ingested food moves slowly through the actual protoplasmic mass of the Amœba's body; not through any definite canal, but forcing its way through the semi-fluid protoplasm, growing in its passage less and less in bulk as the surrounding mass absorbs the nutritive portions, and finally being extruded, as far as the non-absorbed parts are concerned, at any point in the general surface.

(3) Infusoria.—In the microscopic animals that swarm in vegetable infusions a definite mouth is met with for the first time. The members of this large and important class have, for the most part, a definite opening for the in-taking of food. This mouth leads into the beginning of an alimentary canal. It is only the beginning, for the canal or gullet or œsophagus, is very short, and is clogged at its base by the protoplasm of the mass of the body. After passing in at the mouth and down the short gullet, the food has to force

its way through the body protoplasm again, just as in Amœba. But the advance in this case is not only shown in the presence of a mouth and of a commencing digestive tract. It is further demonstrated in the fact that the food-pellets, after plunging into the protoplasm as conclusion of their descent down the pervious œsophagus, take a *definite* course through the protoplasm, moving steadily round just within the outer body-walls. As they thus move round, they become smaller as result of the absorption from them of the nutritious portions, and finally the parts not absorbed by the animal are extruded not at a definite opening, but at a definite *region*. There is no aperture for the egestion as there is for the ingestion, but there is a region. The parts not digested always make their exit from the Infusorium at one particular part of the body.

(4) Hydra.—The little Hydra or Freshwater Polype on the water-weeds presents the next stage in the evolution of the digestive apparatus. Encircled by the long, active, sensitive tentacles is the mouth. This leads into a central cavity occupying the whole of the body and only limited by the body-walls. This cavity is at once the body-cavity, and the digestive cavity. The two are not yet distinct. They are one and the same. The food passes in at the mouth into the cavity that is both gastric (γαστηρ, stomach) and somatic (σωμα, body), is there digested and has its nutritious parts absorbed by the inner walls of the cavity. That which is not used is given out again by the same aperture as that by which the food was ingested.

(5) Sea-anemone.—In the Sea-anemone and its allies a further movement in the direction of complexity occurs. Here, also, is a mouth surrounded by tentacles and opening into a gastric cavity. But the gastric cavity is not one with the somatic. It is suspended within the latter. The Sea-anemone is in truth a double bag, the outer portion consisting of the body-wall, and the inner of the digestive sac. A piece of food passes through the mouth into the latter, then through an aperture in the floor of the digestive sac into the general body-cavity. Thence any indigestible residue makes its escape through the hollow tentacles with their open ends. The alimentary canal is marked off from the body cavity, but opens into it and is not sub-divided into distinct regions.

(6) Entozoa.—The animals that infest the interior of

other animals present in certain cases a mouth and an alimentary canal that is completely shut off from the body-cavity. There is no longer any opening of the one into the other. But the alimentary canal, though it may be divided, is not differentiated off into definite regions, nor has it any opening other than the mouth. The mouth leads into a tube of simple though possibly divided nature, ending blindly and neither communicating with the body-cavity nor the exterior. Still, in the complete isolation of the two tubes, somatic and gastric from each other, there is an advance.

(7) Earthworm.—A mouth, a straight alimentary canal and a distal opening. Here not only is the intestinal tube shut off from the body-tube wherein it lies, but it has direct communication with the exterior by means of two apertures, and not one only. As yet, however, the digestive tube is straight and presents no sub-division into stomach and intestine.

(8) Leech.—In this close ally of the Earthworm, belonging to the same class Annelida, the alimentary canal has all the advantages possessed by that of the Earthworm, with others in addition. The tube is no longer of uniform diameter as in the Earthworm, nor is it undivided. It is expanded at certain regions or sacculated, and it gives off two extensions near the posterior end of the body that end blindly.

(9) Insect.—The higher ringed animals, as the Scorpion, Insect, Lobster, have a mouth and an alimentary canal presenting a clear division into a stomach or special expansion, and an intestine of less diameter than the stomach. The stomach, save in the very highest, is simple and not divided into two or three regions, and the intestine is straight and lies all in one vertical plane.

(10) Mollusca.—The soft-bodied animals, as the Snail, Oyster, Cuttle-Fish, possess all the parts to which reference has just been made. But the stomach in most of these is complex, and divided into two or three parts, crop, gizzard, true stomach, and the intestine is not straight, but coiled, and does not lie in the same vertical plane. Still the intestine is not as yet clearly sub-divided into separate regions.

(11) Finally, in the Vertebrata, the mouth, gullet, stomach, intestine, and terminal opening of the lower animals all appear, and in addition the intestinal region is

clearly differentiated into several divisions, whose numbers and whose difference one from the other increase the higher we ascend in the animal kingdom.

Thus has been traced out in brief the application of the principle of Von Baer to the structure of the digestive organs of animals. It will be noticed that reference has only been made to the morphological phænomena. Histological and physiological advance in complexity have not been considered. They might be worked out along similar lines. And yet more generally every function, and the organs concerned in every function, might be dealt with in similar manner, and would furnish fresh evidence in favor of the principle of the "progress from the general to the special."

CHAPTER VIII.

PHYSIOLOGY OF REPRODUCTION.

HAVING considered certain general physiological principles it seems well to devote special attention to one particular division of physiology. Perhaps none is more important as object of study than the physiology of reproduction. Upon this function depends not the life of the individual, but the life of the species. Adopting the technical name of Genesis (γενναω = I produce) as synonymous with the more ordinary word Reproduction, we pass to the consideration of the function connoted by either of these words. The subject will be considered under the following heads: A. Genesis generally, B. Genesis in Plants, C. Genesis in Animals.

A. *Genesis generally.*—At the outset it is necessary to distinguish between the two chief methods of genesis. A plant may be reproduced by buds, or by slips. Certain animals also are reproduced by budding. And in these cases where only one individual is concerned, to use the ordinary phraseology, the reproduction is asexual or agamogenetic (α = without, γαμος = marriage). On the other hand plants are frequently reproduced by seeds. Certain ovules impregnated by certain pollen structures develope into a plant of like nature to the parents. Again, in animals, certain eggs, or ova, are impregnated by a fertilising agent known as the spermatozöon, and develop into an animal of like nature to the parent. This method of genesis wherein two individuals are as a rule concerned is called sexual reproduction or gamogenesis. For a little while let us pause upon the comparison of, and the relation between, these two methods.

(1) Agamogenesis.—In the budding of plants, and in the budding of new forms from such lower animals as the Hydra, we have instances of agamogenetic reproduction. It is usual to say that in this method only one individual

is concerned. But as in the first place there is some confusion about the use of the phrase "biological individual," and as in the second place gamogenesis assuredly occurs in certain plants and animals within the limits of the individual, a clearer definition is desirable. Agamogenesis or asexual reproduction occurs when the structure that is to be developed into the new being is formed of one cell, or of a series of cells of precisely similar nature. Thus when the yeast-plant, which as a whole consists of but one cell, buds off another precisely similar cell we have a form of agamogenesis. There is no differentiation observable, save temporarily in the matter of size, between the parent and the offshoots from it. Or, again, when a rose-tree gives off a much more complex bud than that of the yeast, that bud consists of a mass of precisely similar cells. It is true that they differentiate afterwards into fibres and vessels, but no contact with, or influence of, some other-natured cell is necessary to set the cells of the simple homogeneous bud on its path of further development.

This form of genesis in which there is no indication whatever of sex occurs during the time that the growth of the individual is most active. There is much more agamogenesis in summer than in winter, much more agamogenesis during youth than during adult life.

(2) Gamogenesis. In the formation of the seeds of plants, and in the formation of the ripened eggs or ova of animals, we have cases of gamogenesis, or true sexual reproduction. The statement that two individuals are always concerned in this method hardly seems exhaustive. Truly in all cases of cross-fertilisation in plants, and in all cases of cross-fertilisation in animals two individuals are concerned. But consider the instances of self-fertilisation in plants, where pollen from the stamens of flower A impregnates the ovule in the gynœcium of flower A, or consider the self-impregnation that occurs in the tapeworm and other parasites upon higher forms of life. Here very clearly two individuals are not concerned. The converse of our definition of agamogenesis may be taken to define this form of reproduction. Gamogenesis occurs when the structure that is to be developed into the new being is formed as result of the junction of two dissimilar plastids or of two dissimilar cells. Thus the plastid, known as the germinal vesicle, within the ovule or

unripe seed of a plant is impinged upon by the contents of the pollen-grain when impregnation takes place. This plastid or germinal vesicle in the ovule is different in structure, different in composition, different in location, different in all its surroundings from the pollen-grain. Here, then, is contact between two dissimilar structures, and this act is an act of sexual or gamogenetic reproduction. Still more different are the two structures that collide in the sexual reproduction of animals. The ovum, or the egg, of the animal, with its external membrane, its highly-organised contents, its central more condensed structure is different in structure, different in composition, different in location, different in all its surroundings from the mobile spermatozöon that is to fertilise it. Contact of two dissimilar structures is necessary for this higher form of reproduction, and it is usual to distinguish the receptive structure from the active structure by the respective names of female and male. The female will be the one that after stimulus will develop into the new being; the male is the one that furnishes that stimulus. No matter how complex the surroundings may be of the act of sexual reproduction, the essentials remain the same throughout. Whether we consider the simple fertilisation one by the other of two threads of a low Alga, or consider the fertilisation of the higher animals with all its complex accompanying conditions that furnish materials for the most intricate problems in sociology, in all cases the one absolute requisite is the contact of these two dissimilar structures.

Sooner or later, however extensively agamogenesis may obtain it would appear that gamogenesis must take place. Offshoot after offshoot may be produced asexually by a plant, but it would seem that at some period or another, gamogenesis must intervene.

It is now necessary to insist upon the fact that the reproductive structures of which we are speaking, are not exceedingly specialised in their nature. The first impulse is to consider that those parts of the organism, upon whose collision such momentous results ensue, would be exceedingly highly organised, exceedingly advanced in their differentiation and development. But on the contrary, the reproductive structnres are those that have undergone least change from the fundamental condition. They are akin to the parts which constitute the whole of the animal or plant in the earliest and simplest condition. Whereas other cells have become transformed, and passed into the condition of fibres and of vessels, these reproductive structures have not changed at all from the primordial condition. In that earliest state all the constituents of the living body have the capacity for reproduction. In the majority of these constituents, that capacity becomes lost. Several pass into other arrangements and assume other forms. But in certain of them this original condition is retained, and the parts of the organism thus retaining the primordial condition and not undergoing change are those whose functions will be reproductive. As still further illustrating this, let it be remembered that even in the highest animals the reproductive *organs*, within which these reproductive structures are developed, are as a rule of the very simplest possible tissues.

As we saw that agamogenesis was most notable when growth was strongest, so do we see that gamogenesis is most notable when growth is at its minimum. By this one does not mean that gamogenesis occurs only when decay has set in, but rather that it takes place when further growth of the body does not occur—when the organism is at its strongest and best, food supply being wholly used in the maintenance, not in the extension of the body. A condition of moving equilibrium in effect now obtains. Thus gamogenesis is more marked in the winter than in the summer, is distinctly the function of the adult and not of the youthful condition. Finally, as further illustrating this important principle, it should be observed that the more nutrition there is, the less the probability of gamogenesis. Over-feed a plant, it will bud perhaps but not seed. Over-feed and over-burden with luxuries the man, and there is deterioration of the productive power and of the offspring that may be produced.

B. *Genesis in Plants.*—(1) Agamogenesis. The asexual form of reproduction in the vegetable kingdom is exhibited in budding chiefly. When in the angle between the leaf or leaf-scale and the stem of a Lily a little collection of similar cells appears, becomes detached from the parent plant and, fixing itself into the ground, grows up into a new Lily, we have a case of budding or germination (gemma = a bud). The propagation of plants by slips or cuttings, wherein a small piece of stem, bud-bearing, detached from the plant and placed in the ground developes into a whole plant, or, by layers wherein the piece of stem to be detached is made to strike root ere it is separated from the parent stock, these forms of propagation are again agamogenetic.

(2) Gamogenesis.—The sexual method of reproduction implies the contact with one another of two dissimilar structures. In the higher plants these are the pollen-contents or male or stimulating structure and the plastid within the ovule. This plastid is the female or receptive structure. The pollen-grain is a cell with two coats and rich contents. The ovule or unripe seed contains within it a sac or case known as the embryo-sac. Within this sac are two or three plastids—*i.e.*, masses of protoplasm not surrounded by a definite cell wall. Of old time it was held that the pollen-grain of any given flower fertilised the plastid contained in the ovule of the same flower. This self-fertilisation is, however, very rare. In the forthcoming "Students' Darwin," by the present writer, will be found a full account of that cross-fertilisation, wherein the plastid of a given flower is fertilised by pollen from another flower of the same kind. It will suffice here to state that whilst self-fertilisation is rare, cross-fertilisation is very common. The inevitable question arises, How is it affected? How can pollen from one flower pass to the stigma or summit of the female organ of another on its way to impregnation? In two ways. (*a*) By the agency of the wind. Consider the Oak-tree. In the spring days, the Oak hangs out long, little yellow tails that are collections of male flowers, and whose golden hue is due to multitudinous pollen-grains. In the same tree, but in different parts, you will find quiet, unobtrusive female flowers with stigmas tinged with crimson. The pollen from the yellow tails is borne by the spring breezes to the tips of the tiny female flowers and impregnates the plastids in the one or two ovules. Oaks, Hazels, Beeches, Willows, Poplars, Alders, Birches, Grasses, Plaintains, a score of other plants, are thus wind-aided in their genesis. Such plants are named anemophilous (ανεμος=wind, φιλεω =I love). They are known by these marks. (i.) The flowers are formed ere the leaves. Thus the leaves do not get in the way of the wind-driven pollen and prevent it reaching the stigma. (ii.) The flowers are humble, having no brightness of hue, nor odor to attract the senses.

(iii.) They do not produce nectar or honey. (iv.) The amount of pollen-grains formed is enormous. This would seem to be necessary, when consideration is had of the vagueness of wind-currents, and of the fact that the odds are against pollen being carried to the exact place where the stigma sits and waits. (v.) The stigmas are hairy, and thus catch the floating pollen-grains with greater ease than would be within the power of smooth stigmas.

(*b*) By the agency of insects. Consider a Violet. The pollen of this plant is borne by insects to the stigma of a kindred flower. Orchids, Foxgloves, Lilies, Roses, Buttercups—hundreds of other plants are thus insect-aided in their genesis. Such plants are named Entomophilous (εντομον =insect). They are known by these marks. (i.) The leaves appear before the flowers. (ii.) The flowers are gay. They are colored, remarkable in shape in many cases, and often odorous. (iii.) They produce nectar, the reward of the insect. (iv.) The amount of pollen is small in most cases. The insect comes in such definite manner and carries the pollen so unerringly from one flower to the stigma of another, that the waste of pollen in the former case does not here occur.

Of the value of this far more frequent cross fertilisation mention has already been made in connexion with the strength of the resulting individual and with the greater possibility of variation occurring under these circumstances. The whole question as well as that of the sex arrangements in plants generally will be found dealt with at large in the book to which reference has been previously made.

C. *Genesis in animals.*—It is proposed here to deal with Herbert Spencer's grouping of methods of genesis and then to attempt to show the gradual growth in complexity in the methods of reproduction as we ascend through the animal kingdom. (1) Herbert Spencer's grouping. Genesis is reproduction. Of it are two chief methods. (*a*) Gamogenesis associated with agamogenesis; *i.e.*, sexual and asexual reproduction occur in a living being. And this he names Heterogenesis (ἑτερος=other). (*b*) Gamogenesis occurs, alone. And this he names Homogenesis (ὁμοιος=like). Each of these methods subdivides. Thus (*a*) Heterogenesis may take the form of (i.) production of new beings indifferently, from no specialised region of the body. And this is Metagenesis (μετα=after). (ii.) Production of new beings from structures formed within an organ resembling but not identical with the female organ or ovary. And this is Pseudo-parthenogenesis (ψευδος=false, παρθενος=a virgin). (iii.) Production of new beings from structures formed within an actual ovary, but *not* fertilised by any male structure. And this is Parthenogenesis. Of these three divisions (i.) Metagenesis presents two forms. *α*. External metagenesis. *β*. Internal. Finally (*b*) Homogenesis wherein sexual reproduction occurs alone and unaccompanied by asexual genesis may take the form of (i.) Oviparous (*ovum*=an egg, *pario* =I bring forth) when the product of the act of genesis is an egg, and the new being quits its parent in the form of an egg. (ii.) Ovo-viviparous, where though an egg is formed, it undergoes partial development within the body of the parent, and emerges as a living creature no longer egg-like. (iii.) Viviparous (*vivum*=a living thing), where the young comes into the world a living being in the ordinary sense of the word.

These various forms of reproduction will now be arranged in a tabular form, and an example of each, generally from the animal kingdom, given. In one or two cases illustrations from the vegetable kingdom will be taken.

Genesis.	(*a*) Hetero-genesis	i. Metagenesis	*α* External ...	Lily buds; Hydra buds.
			β Internal...	Barnacle.
		ii. Pseudo-parthenogenesis.		Aphis.
		iii. Parthenogenesis.........		Psychidœ.
	(*b*) Homo-genesis	i. Oviparous..................		Flowering plants; Birds.
		ii. Ovo-viviparous		Shark.
		iii. Viviparous		Man.

(*a*) i. *α*.—The external buds of any ordinary flowering plant call for no special comment. The Hydra, or fresh-water polype, may give off from points on the exterior of its body buds that rapidly develop into complete Hydræ, and, detaching themselves, lead an independent existence.

(*a*) i. *β*. In the development of the strange Barnacle the egg does not form an adult Barnacle at first. It grows into a larval form. Of this larva there are three stages.

Within the larva in its third stage is formed the adult Barnacle. This last is a case of Metagenesis.

(*a*) ii. In Aphis, or the plant-louse, the first products of the eggs resulting from gamogenesis are sexless insects. These sexless insects approximate to the female type. Within an organ that in position, and to some degree in structure, suggests an ovary, a brood of Aphides forms. These are set free, and in their turn produce in similar rudimentary organs a fresh brood. And this process continues for nine generations, so that from one Aphis as many as several millions can be produced in one summer. This formation of new beings within an organ resembling an ovary approaches the next method, and hence derives its name.

(*a*) iii. Certain insects have females possessing complete ovaries that contain ova or eggs. These ova, without any contact with or stimulus from a male cell, develope into perfect insects. There can be no doubt of the truth of this remarkable statement.

(*b*) i. and iii. call for no special comment.

(*b*) ii. In the shark, as in all other fishes, an egg results from the act of gamogenesis. But that egg is not, as in other fishes, extruded from the body and hatched outside the body. It is hatched within the parent, and has even a connexion with that parent during a part of the intra-maternal life curiously suggestive of the placenta of the Mammalian animal.

(2) Von Baer's law applied to reproduction. It is designed in this connexion to trace out the various methods of reproduction in animals from the simplest conditions to the more complex. But as, in studying any function in full, it is impossible to wholly exclude one form of living things and entirely confine attention to the other, reference must be made to the plants and illustrations from them be used. (*a*) Principles. (i.) Taking Von Baer's law of progress from the general to the special as our guide, we shall endeavor to describe briefly the various methods of reproduction encountered in the animal kingdom. We shall find, as usual, least specialisation at first, and more specialisation the higher we ascend. (ii.) A second principle for our guidance is this. Multitude of offspring is not lofty reproduction. Lowly organised plants and animals produce

a great quantity of offspring, but whilst the quantity is great the quality is poor. The further down a living being is in the scale of living beings the more numerous its progeny, and the more identical are the individual members of the family one with another. Where the descendants are so numerous there is little chance of favorable variation in the direction of higher conditions. It is almost unnecessary to point out that this principle obtains right through the two great living kingdoms. The highest member, man, of the highest kingdom, animal, is a striking case in point. The worse than foolish people who bring into the world families huge in number almost invariably have children of a low type muscularly, mentally, morally. Repetition of similar parts means lowness of organisation. Thus the centipede, with its numerous body segments, each one resembling in the main all the rest, or the tape-worm, with its body segments still more numerous and still more identical, are ringed animals far more lowly organised than the insect, with its few segments all differing in a greater or less degree the one from the other. And this principle, that repetition of similar parts means lowness of organisation, applies in relation to reproduction. The repetition of child after child means that these children will be terribly similar in weak physique and inferior mental power. It is the business of the human beings who believe in evolution to transmit purity and strength both of body and mind to their children, and to a few of those children, not to many.

(iii.) Again, for the thorough comprehension of the evolution of reproduction, it is essential that the reader keep in mind that the best results follow when dissimilar structures come into collision in the production of the new being. The greater the similarity of the structures concerned in the act of reproduction, the less advantageous is the result. Hence we shall find such similarity in the reproductive structures of the lower living beings, and we shall find dissimilarity in the reproductive structures of the highest living beings.

(*b*) Grouping. (i.) Agamogenesis. Clearly agamongenetic or asexual reproduction is lower than gamogenetic or sexual reproduction, by the very definition given in the preceding pages. Agamogenesis we should expect, therefore, to find very prevalent in the more lowly organised animals, and gradually disappearing as we pass up the great kingdom. And this is precisely what we do find. Attempting, with no little misgiving, to arrange the methods of agamogenesis in philosophical order I place first

(*α*) Encystation. The gregarine that crept into all the newspapers, some few years back, on the supposition that it had been creeping into the false hair worn by women, an animal that is known certainly as infesting the cockroach and the earthworm, reproduces itself by encystation. This oblong-shaped, microscopic being, having structure of the very simplest order, consisting, indeed, of nothing more than a single cell, gathers itself up into itself and becomes spherical. Then the spherical gregarine is investsd with a gelatinous surrounding, and within this case its body breaks up into a large number of pieces. Presently the case bursts, and each of these little pieces, in reality a plastid or mass of protoplasm escapes and grows up into a complete gregarine. The reproduction here is agamogenetic. The structures concerned are all alike. No collision of two different structures is apparently involved. The offspring are very numerous. In all respects, therefore, a low method of reproduction.

(*β*) Fission. The class Infusoria, including the minute animals that float about in dirty water, wherein plants have been living, present this method of agamogenesis. Here an individual infusorium, which again is nothing more than a single cell, splits into two equal pieces each of which becomes an infusorium like the original cell. In this case the number of offspring is only two, and we have a considerable advance upon encystation, but the two are from the first exactly alike one another and the parent.

(*γ*) Gemmation, or budding. Certain infusoria at certain times instead of splitting into two equal divisions bud off a small portion of their body, which grows very rapidly to the same size as the original animal. As far as the number of offspring is concerned, gemmation ranks level with fission, but I am inclined to place it higher in the scale because of the fact that one of the offspring produced is smaller than the parent, and has to undergo some small amount of development before it resembles the parent. And this seems to me to imply a higher condition of reproduction than the former.

(*δ*) **Rejuvenescence.** In this last method of agamogenetic reproduction the unicellular being produces within itself a single descendant. The case is the same as encystation except that instead of the one cell-body breaking up into many pieces, within the external case is formed a single individual only. If one may be allowed the analogy it is a case reminding us of the old fable of the Phœnix. There is no increase in number—there is only a continuation of existence. This rejuvenescence or formation of one one-celled structure within another whose existence terminates with the commencement of that of the former, appears to be the highest form of asexual reproduction. It is best seen in the plant kingdom in the development of pollen-grains.

(ii.) Turning now to Gamogenesis in living beings the following methods are encountered:—

(*a*) Conjugation. By that is meant the coming together of two structures not at present distinguishable from each other, and their impregnation the one by the other. This conjugation is best seen in the plant kingdom. Two threads of a water plant exactly alike in appearance are lying side by side in some still pool. Each of them gives out a little extension on the side nearer its fellow. These protrusions or extensions grow to greater and greater length, at last meet, melt into each other, and the interiors of the two threads are now in communication. Their contents mingle and form generally a single structure, which, liberated by the decay of the parent threads, will grow up into the green water plant again. The structure thus formed is clearly a seed and is known as a Zygosperm (ζυγὸν=yoke, σπερμα= seed). Here then is actual impregnation of the contents of the one thread by those of the other. But the two threads are exactly alike; their contents are precisely similar. It is impossible to say which is stimulating, or male, and which is receptive, or female. Spirogyra of the fresh-water Algæ is a case in point.

β. Self-impregnation. In almost all animals the male and female structures are readily discernible the one from the other. But at first they are located in the same individual animal. The low members of the kingdom are bisexual or hermaphrodite, each individual containing both male and female structures. In the lowest class Polyzoa of the soft bodied kingdom we find colonies of minute animals. Each member of the colony is bisexual. Its sexual organs are enclosed within its body wall, and probably their contents are discharged into its body cavity. Nothing but self-impregnation, that is the impregnation of the ovum or egg produced by the female organ, by the spermatozöon produced by the male organ of the same animal appears possible here. In the body cavity of each individual this self-impregnation takes place.

(γ) Self impregnation and Mutual impregnation. In many Entozoa, animals parasitic within the interior of others, the arrangement of the sexual organs is such that self-impregnation may occur. But there is also provision for the mutual impregnation of two individuals one by the other and the other by the one. Thus in the Flukes that infest the liver of sheep we find both sexes represented in each individual animal, and the sexual organs so arranged that one of two things may occur. Either the spermatozoa of a given individual come into contact with the ova of the same being and self-impregnation takes place, or two different individuals come together and the spermatozoa of the one pass to the ova of the other, whilst the spermatozoa of that other are also passing to the ova of the one. And this method we shall call mutual impregnation. It will be observed that these animals have mutual impregnation associated with the lower forms of self-impregnation.

(δ) Mutual impregnation. In such animals as the snail, of the class Gasteropoda, and the leech and earth-worm of the class Annelida, mutual impregnation alone occurs. It is no longer associated with self-impregnation.

(ε) Cross-impregnation. So far we have had fertilisation of one structure by another identical with it, that is, conjugation, fertilisation of the receptive ovum by the stimulating spermatozöon within the limits of the same individual, or self-impregnation, and that mutual impregnation in which an individual animal is at once the fertiliser and the fertilised. But now we come to cases where the sexes are completely separated. The animals that are now considered are unisexual. Each is either male or female. As we study these, we shall find the fertilisation of the ovum of the one animal by the spermatozöa of the other, at first left very considerably to hazard, and as we ascend we shall observe the contact of the two dissimilar structures becoming more and more definite and certain. Thus:—1. In the starfish and many of its allies it would appear that the eggs are cast out into the medium around, and the spermatozoa are in like fashion extruded into the water. The male and female structures, thus diffused through the medium in which the animal lives, may on certain occasions come into contact, but there must be multitudes of ova and spermatozoa that perish before meeting with spermatozoa or ovum, and, therefore, without performing their function of reproduction. 2. The next stage is an advance upon the diffusion of both male and female elements into the surrounding medium. It involves a transference of the male element by the medium to the female. In the higher Mollusca, such as the cuttlefish and other members of the class Cephalopoda, the ova of the female remain within the ovaries, but the spermatozoa of the male are discharged into the water, and take their chance of reaching the external opening of the reproductive organs of some female. The method is less vague and indeterminate than the preceding one, but is still wanting in precision. 3. Direct impregnation. In the higher ringed animals, or Annulosa, and in almost all Vertebrata, there is an advance upon that method of impregnation which depends upon the transference of male structures by the medium. In the insects, the reptiles, the birds, and the mammals, there is the direct introduction of male fertilising structure into female organism, and in this way fertilisation is rendered almost certain. I have written almost all Vertebrata above, inasmuch as in the class Pisces there is a curious remnant of the earlier method of reproduction. Most fishes lay their eggs before fertilisation, and then, after these eggs have been extruded from the body, the male element is directly placed upon them. This is an interesting transition between impregnation by transference through a medium and direct impregnation. Yet another instance of transition between these two, with still closer approximation to the second, is shown in the method obtaining in certain Amphibia. The female frog, for instance, lays her eggs before impregnation, but at the very moment of their extrusion they are fertilised by the male.

CHAPTER IX.

DEVELOPMENT.

WE have studied in the last chapter some of the chief points in connexion with the process that is of service in maintaining the life of the species, of the race rather than that of the individual. That process is known as reproduction. Something of the physiology of reproduction has been investigated. Reproduction produces an embryo. That embryo has to pass through many stages, to undergo many changes ere the adult condition of the plant or animal is reached. The succession of changes whereby the embryo of such plant or animal becomes the adult is known as development.

By development of a plant or an animal, we mean its increase in mass or its growth combined with its alteration from a condition of less heterogeneity to one of greater heterogeneity. This alteration is its differentiation, and therefore development = growth + differentiation. The development of a living being, therefore, means the series of changes through the which it passes in its transformation from its simplest and earliest condition to its most complex and most complete condition. The development of a man is the history of the changes occurring during the time that the first simple cell within the mother gradually evolves into the adult human being.

In the necessarily brief survey possible to me, I shall consider: (A) The two chief divisions of the study of development. (B) The theory of Pangenesis. (C) The evolution of development.

(A) *Divisions of Development.*—These are two. We may either study the development of the individual or the development of the race. The investigation of the stages whereby the individual passes from its first to its full life is known as Ontogeny (from ὢν = a living being, and γενος = descent). The investigation of the development of allied forms one from another, which in truth involves an inquiry into their blood-relationships one to another is known as Phylogeny (φυλον = race). If we follow out the metamorphoses of an insect as egg forms caterpillar, caterpillar becomes chrysalis, within the chrysalis the imago or perfect insect developes and bursting its bonds flutters out into the sunshine, we are studying Ontogeny. But if we ask how this insect is related to its fellows or to the lobster or the scorpion, what resemblances between these animals and others obtain, how we may search out the lines along which they have evolved from common parent, then we are studying Phylogeny.

(B) *Pangenesis.*—It is plain that in the study of Phylogeny the recognition of the principles of transmission from parent to child, of inheritance on the part of the child from the parent come into play. That such transmission of qualities even of the most special and peculiar nature exists the most common-place observer observes. That children inherit the characteristics of their parents even unto the third and fourth and far more distant generations is familiar to all. Is there any convenient hypothesis, convenient if temporary, that helps us to comprehend and in any way connect these innumerable facts of transmission and inheritance? There is the hypothesis of Pangenesis (παν = all). It is a hypothesis of Charles Darwin. It suggests that every part of an animal or a plant body—every part of a living being is constantly casting off from itself particles infinitely many, infinitely minute. These innumerable, immeasurable particles called gemmules have the character of the organ, part or tissue from which they proceed. They gather together in ova, the eggs, or in spermatozoa, the male elements. Now, as the new being results from the coming together of ovum and spermatozöon, from the structure of the one blending with that of the other, we may opine that the commencing structure of the new being consisting of these twain, will contain gemmules from all parts of both parents. Therefore in the first stage of the development there will be multitudinous gemmules from both parents with all the structure and all the tendencies of the gemmules given off from the parent organisms. That these under favorable conditions should group themselves together and reproduce in the offspring the structural and functional arrangements encountered in the parent or parents even to the minutest particulars is not beyond comprehension.

(C) *Evolution in Development.*—It remains to trace out, with Von Baer's law for our guide, the various stages met with in the development of different members of the animal kingdom. (1.) Plastidular. The lowest animals, in the whole of their life history, never rise even to the condition of a single cell. They are nothing more than unenclosed protoplasm. They are plastids. Such beings as Amœba come under this category. (2.) Cellular. The next stage is represented by the class Infusoria. Here a single cell represents the whole and complete animal. The cell, we have seen, is an advance on the plastid. It has a definite surrounding wall limiting the protoplasm. Of the animals whose development involves the production of a cell, we have—*α*. Those only forming one cell: the unicellular. *β*. Those formed of many cells: the multicellular. Of the division *α* an example has been given.

Turning to *β*, the multicellular, we find two groups. 1. Some animals consisting of more than one cell, but all the cells are alike. Each is a repetition of each of its fellows. No differentiation has occurred. Of this condition are the Thalassicollidæ (*θαλασσα* = sea, *κολλη* = glue). 2. Some animals consisting of more than one cell, and the individual cells different each from others. Now definite tissues and organs appear. These multicellular animals, in whom differentiation has taken place, may have the parts of their body arranged indefinitely, or arranged symmetrically with reference to certain lines or planes. Thus the very lowest Mollusca consist of several organs composed of several tissues, but there is no main line of symmetry around which the parts of the body are grouped. Such development I would call anaxial, without an axis. The Polyzoa seem to exhibit this condition. But higher in the scale than this the body organs clearly are arranged in definite relation to one or more axes.

Of this axial development we find at first instances wherein the axes of symmetry are several. Consider the starfish. Here is a body with five arms. Each arm has the structure of its companion arms. Each arm has certain parts within it disposed symmetrically in relation to a vertical median plane. The starfish is multiaxial. Yet higher and the axis of symmetry becomes yet simpler. In the Ascidian, possible representer of the far-off forerunner of the Vertebrate sub-kingdom, the openings of the body are two One is the mouth. The other may be approximately taken as the opposite termination of the alimentary canal. They are adjacent one to the other. And the organs of the body are disposed, on the whole, symmetrically upon opposite sides of an axis that runs from the mouth to the lower end or base of the body and then forwards again to the opening not far distant from the mouth. In this case the axis of symmetry is double, and its two parts make an angle each with the other. It may be regarded, perhaps, as representing the axes of two arms of the starfish instead of five.

Next this double axis, with its two parts making an angle with each other, passes into an axis that is curved. This may be compared with the preceding case by imagining the angle made by the two axes in the former case to open out, and the two axes originally meeting at an acute angle to glide into each other and to form a curve. And this arrangement of organs on opposite sides of a curved axis of symmetry is seen in some of the Mollusca, or soft-bodied animals.

In yet higher members of the great kingdom the axis becomes one straight axis. All the truly ringed animals and all the great sub-kingdom of Vertebrata show this method. But even of this development in relation to one straight axis there are divisions. Let us remember that repetition of similar parts means lowness of organisation. Then let us consider the Tape-worm with its very numerous similar segments, none of which save the very foremost carries any limbs or other appendages. From this pass to the leech with fewer segments but yet a large number, none of which save the foremost carries limbs or other appendages. Thence pass to the earth-worm still with many like body segments, each of which carries small tufts of hairs as rudimentary appendages. In the centipede the number of segments is yet further reduced and the appendages are defined and comparatively complex legs. But the body is only marked off into two regions, viz., a head and a region succeeding thereto, and the limbs are very many and all alike. In the yet higher insect class the body has three defined regions, head carrying sense-organs, thorax carrying motor organs (wings and legs), and abdomen or posterior part of the body. The segments of these three several regions are diverse in structure. Even the segments of one special region are not alike. And the appendages are much more defined and differentiated. Now they have become eyes, antennæ, jaws, three pairs of legs, and two pairs of wings. In the lobster, perhaps the highest stage in invertebrate animals is reached. The three regions are well marked-off. The appendages are very much more subdivided and complex than in other animals.

Finally in the Vertebrata the organs are arranged symmetrically on each side of a median axis, and the exceedingly highly differentiated limbs are reduced to two pairs.

Hence in this brief survey we are able to observe development at first never passing further than the plastid stage; next rising as far as the unicellular condition, then passing into the formation of animals of many similar cells; anon to the differentiation of those cells. And when the many cells begin to differ and fibres and vessels are forming, the development may be so indefinite that no main axis of symmetry is evident. Or such an axis or axes may be observable. The axes are at first several. Next they would seem to be reduced to two, at an angle with one another. This angle opening out we have a curved axis of symmetry. The curved axis becomes a straight one and at first many similar unappendaged segments are ranged in relation to it. The number of these segments diminishes, their difference from each other increases, they develop appendages, whose number, at first great, lessens, and whose structure becomes more complex until we reach the higher ringed animals and finally the Vertebrata. Appended is a table that may render this complex subject plainer to the reader:—

- Development.
  - Plastidular.
  - Cellular
    - Unicellular.
    - Multicellular
      - Without Differentiation.
      - With Differentiation
        - Anaxial.
        - Axial
          - Multiaxial.
          - Binaxial.
          - Uniaxial
            - Axis curved.
            - Axis straight
              - Without appendages ... Tapeworm. Leech.
              - With appendages
                - Many bristles... Earthworm.
                - Many legs ... Centipede.
                - 10 legs ... ... Lobster.
                - 6 legs, 4 wings... Insect.
                - 2 arms, 2 legs... Vertebrata.

CHAPTER X.

ÆTIOLOGY.

ÆTIOLOGY (*ἀιτια* = cause) is the consideration of the causes of the multiform phænomena visible to-day. Until recently Ætiology consisted of the word god. It was held sufficient explanation to say that certain things happened because god willed it. But attempts have of late been made to explain the phænomena of Nature in a less lazy and more real way than this. Charles Darwin most of men has helped us here. Indeed any account of Ætiology can be but excerpts from his teachings. Here therefore the subject will be only briefly discussed. It is treated at much greater length in the present writer's "Student's Darwin."

In this connexion it will suffice to deal very briefly with the great doctrine of evolution as explainer of things, after the fashion of Herbert Spencer. We shall not pause to give all the myriad facts in favor of the view, but rather follow him in his excellent summing up of the two rival hypotheses of evolution and special creation.

At the outset let us be clear as to the meaning of these two phrases. Special creation supposes a power outside Nature which plans and carries out every event therein. Not alone is every species of plant and of animal called into being by the distinct effort of will of this power, but all events of geological or of sociological history are arranged and carried out by the same power. There is no necessary connexion between one stage and its successor or its predecessor. All is of god. Evolution, on the other hand, means development. The many species of plants and of animals existent to-day instead of being individually created by god have grown gradually out of a few primordial forms or out of one primordial form. So also to the evolutionist not only living beings are evolved. All events grow steadily, inevitably one out of the other. The phænomena of geology or of our complex social life of this nineteenth century are not to him the result of will-efforts on the part of a deity, but the consequences of past phænomena. The variations of minerals, of plants, of animals, of the highest animal, man, have under certain general principles, such as natural selection and sexual selection, resulted in what we have before our eyes to-day.

Following Herbert Spencer we compare these two views. First we look at the view of special creation in certain aspects. Then evolution will be regarded in similar manner. In the former case we shall find only the unthinkable and the incomprehensible. In the latter we shall find the thinkable, the comprehensible. In the one case darkness and mental death. In the other light and life.

A. Special creation. (1.) This belief is old. And that is an argument against it. If we have to compare two opposed hypotheses the younger is the more likely, other things being equal, to be the more true. For the older hypothesis is of the world's childhood or even of its infancy. The younger is of the world's riper years. After the fashion of Mr. Hardcastle we love old things—"old wines, old books, old friends." But we dare not forget that old habits of thought are really those of the young world. They are the utterances of man in his cradle. "When I was a child, I spake as a child, I understood as a child, I thought as a child: but when I became a man, I put away childish things." Nobody would oppose the fancies of his early years to the thoughts of his maturer ones. The crude ideas of the child are rejected for the more reasonable and serviceable ones of the man. So also, save in this one question, nobody opposes the crude ideas of the child-world to the more accurate ones of the maturer world of this hour. We have abandoned our forefathers' methods of dress, of travelling, of feeding, of fighting. Yet in a matter not less important, the matter of thought, we cling still to the old-world notions. No phrase is more misleading than "the wisdom of our ancestors." It is as if we spoke of the wisdom of our babyhood. In no other particular are we willing to follow that wisdom, save in the momentous question between special creation and evolution, or more honestly between religion and science. The first objection to the hypothesis of special creation is its antiquity.

(2) Its bad companions. We judge of the nature of a man by his companions. We may judge of the nature of a hypothesis in like way. Now the companions of this belief in special creation are disreputable in many cases, discountenanced in all. The Fetish-worshipper is a special creationist. Ask the Polynesian savage how things came. He answers, "The fetish or fetishes created them." Polytheism, or the belief in many gods, went hand in hand with the same creed. Scarcely a Greek or Roman had a conception of evolution. We may, perhaps, except Aristotle. The conception of God as man-like, or the anthropomorphic deity (*ανθρωπος* = man, *μορφη* = form), had, as its companion, special creation. The coarse creed that held deity as man-like and garden-haunting, rejected to-day by all Christians outside the Salvation Army, was inseparably united with this old idea. Fetishism, polytheism, anthropomorphic god are all abandoned to-day. And yet the belief that was part and parcel of them is held by those who shrink in disgust from these old conceptions of the purblind time.

Very curious is it to note that special creation is incorporated with all the Oriental cosmogonies, so that men believing in it reject all of these old cosmogonies save this one part. They smile at ninety-nine hundredths of these fanciful pictures of the past, and retain the one hundredth.

(3) Absence of facts. Not one single fact is known in support of the theory. Not one. It rests solely upon the earlier chapters of the Bible, and upon nothing else. Is it not appalling that men still subscribe to a doctrine that is entirely unsupported by fact? No case of special creation has ever been observed. No single carefully recorded scientific observation supports it.

(4) Unthinkable. Whilst to a certain class of minds the last statement will carry more of conviction than any other, the present will appeal to another order of thinkers. Many will at once reject a belief that has not one fact on its side. Others of a particular bent of mind will be more moved by the statement that intrinsically the theory fails. It is not only that no outside facts support it. It cannot support itself. Grant that no facts bolster it up. It cannot support itself. It has not inherent strength to stand. Left to its own resources, it collapses. And that this is the case may be shown in two ways. (*a*) Special creation, as its very

name implies, involves creation of matter or of motion. If any new being comes at the will of god into the world, there is a creation of matter. If any new force springs at the will of god into being, there is a creation of motion. Neither of these is thinkable. It is quite impossible to realise in thought creation of matter or of motion. To do so we have to link together in thought something and nothing. This is beyond our power. We have to conceive of a moment when, for example, man was not, and a succeeding moment when man was. We have to link in thought two terms, of which one is inconceivable. And further, as has been shown in preceding pages, all evidence goes to prove that matter, though convertible from one into other forms, is indestructible, and in like manner that motion, though convertible from one into other forms, is indestructible. And as they are indestructible, we are driven to the belief that they are also increatable. Both are eternal.

(*b*) Special creation does not go far enough. Its advocates tell us that god in his wisdom and power has created every species separately, and that the grand end and aim of his wonderful works is to instruct man and lead him to god. If this be the case, it is great matter for regret that god performed so many of the most wonderful works before any man was living to be instructed and to be led. It is also to be regretted that god has taken so much trouble to prevent man from knowing, struggle he never so bravely, much that took place in the past. Matters would appear so to have been arranged that much of the history of the dead and gone times can never be truly known. And again, if god created species distinct one from another to move the wonderment of man, it is matter for regret that he did not go a stage further, and create individuals distinct one from another. If we saw every hour of every day new individuals springing into being without any relation to precedent forms of matter, we could not cleave to evolution, we could but accept special creation. Never beholding such special creation of individuals, but seeing these constantly evolved from other individuals, we are led to believe that this latter method has always obtained, and that special creation has never taken place.

(5) Involves the idea of a wicked supreme power. The

notion of Special Creation is synonymous with what is often erroneously called the Design argument. It should be named the Design assertion. If special creation be true, the same power that has been the designing cause of all that is good must also be responsible for all the evil. He that is planner and cause of the pleasure in the world is planner and cause also of the pain. It is an old story, this. The difficulty has been pointed out times and again, and nobody has ever yet given an explanation in the least degree satisfactory. It is impossible to reconcile the notion of an all-wise, all-powerful one with the presence of evil and agony in the universe. And yet this impossibility has to be accomplished by the believer in Special Creation.

It remains under Ætiology to discuss the doctrine of Evolution in the same way as we have discussed that of Special Creation. We shall look at it from the same five points of view whence we surveyed the older theory, and where we found the latter fail in every particular we shall find that Evolution serves us in every particular.

A. Its Youth. Evolution is a young theory. It is only of comparatively recent date. Hardly the dream of it had entered into the mind of man one hundred years ago. The actual statement of the theory in full with evidence in its favor, and reasoning as to the methods whereby Evolution had taken place, all have been within the last twenty-two years. It was in 1859 that "The Origin of Species" appeared. One may say that this book has just attained its majority, and rejoice at the promise of strength and beauty in the manhood that lies before it. As it was urged as an objection to Special Creation that the belief is an old one, because that age showed that it was a belief of the world's babyhood, so is it an argument in favor of Evolution that the belief is a new one. Its youth shows that it is the outcome of the world's maturer thought. With the world as with the man, the explanation "god wills it," or "god does it," is sufficient at first; but as world and man grow older that explanation ceases to suffice. No stockbroker allows god to enter into his calculations as to the rise and fall in stock. No statesman in reality takes god into consideration "in playing his high chess-game, whereof the pawns are men." So the scientific folk of to-day never allow the god idea to enter into and mar their calculations.

Nevertheless, it is necessary to protest against the manner in which a few scientific folk and all the unscientific ones continually drag in the name of no meaning in connexion with scientific discussion.

B. Its good companions. We saw that Special Creation was doomed by the evil nature of its companions. On the other hand we shall find that the character of the theory of Evolution is most excellent, if we found our opinion upon the nature of its comrades. With it all the new developments of thought go hand in hand. It is deeply interesting to notice that in every special science and every special art there is acceptation of Evolution. It is perhaps less interesting, but certainly curious, to notice on the other hand that those who accept Evolution within the range of their own particular study are frequently very unwilling to accept it outside that study. To take one illustration. The study of Philology or the development of language to-day is based upon the idea of the evolution of language. No philologist believes in a tower of Babel. No philologist believes that any language sprang into being after the fashion of Minerva full-formed, full-armed from the head of Jove. Every philologist tells you that every language is the result of slow development from the early interjectional and ejaculatory forms of expression of savage races. And yet many a man eminent in this science—even as eminent as Max Müller—is an earnest, religious man, and scoffs at the idea of biological evolution. Not only is the study of language a companion of Evolution. Geology has of late years undergone very considerable changes in its method. The old geologists had an infinite belief in cataclysms, but the geologists of to-day will tell you that far more has been done by slow—very slow—changes, working through enormous lengths of time, than by any sudden outburst. If the reader will refer to a former page of this work he will see a case in point, and he that reads the works of Sir Charles Lyell on Geology and contrasts them with the works of the earlier part of this century, will observe how notable a change has come over geological science, and how the geological thought of to-day walks side by side with the theory of Evolution. To take one other case. In politics men are growing to recognise the working of the great principle. The whole study of political history is a study of its manifestation. The slow rise into power of first one nation and then another: the slow rise into power of first one group in the nation, as clergy or barons, then, as is occurring to-day, of the people as a whole, "point the moral and adorn the tale." No thinking man believes that a political party springs suddenly into existence. A few years back such a thing as a Radical party was unknown in England. There were, as there had for some time been, as there are even now, two great parties, called Conservative and Liberal. But the student of the history of the last hundred years is able to trace the gradual evolution of a third political order. The party of the people had in reality hardly any existence before the Revolution of 1689. Since then it has been slowly developing, and to-day has to be taken into very earnest account in all political questions. There are even some who think that on the principle of the survival of the fittest it will in time become the strongest and most dominant of all political orders.

C. Facts. We saw that there was no single fact—absolutely none, to support the doctrine of Special Creation. It is now our duty to record that the name of the facts supporting Evolution is legion. It is not too much to say that every observed fact in the past history of science is in favor of the view. Very grateful also is it to evolutionists to notice how the new facts that the energy of man is hourly observing and recording fit in, every one of them, with the teaching of Evolution. Time and space would fail to deal with one tithe of the supporting truths, but it may be well to point out one or two general sets of facts, familiar even to the non-scientific reader, that are altogether in harmony with the doctrine of Evolution, and altogether discordant with that of Special Creation.

For example: (1) Rudimentary Organs. These are organs reduced so much in size and in function, as to be of no value in the working of the animal or plant body, but yet representing organs fully developed and fully working in other plants or animals. Familiar examples are the rudimentary hairs on the back of the human hand, the rudimentary cæcum in the human alimentary canal, and the wisdom teeth of human beings. Now, these rudimentary organs are entirely unintelligible on the older theory. They are quite intelligible on the newer, because they are remnants of structures that in an ancestral form were of use to the individual possessing them. The whole of this subject is discussed more fully in the Author's "Student's Darwin," to which previous reference has been made. (2) Classification. The wonderful gliding into each other of the groups of living beings—a puzzle to the systematist, a delight to the evolutionist—is again incomprehensible on any theory save that of descent with modification. (3) Embryology. The higher animals in their developmental stages, before they reach the adult condition, pass through conditions of structure representative of the permanent condition of lower animals. That this should be the case is once more unintelligible and meaningless, unless we admit that those higher animals have been evolved from lower forms.

D. The reasonableness of Evolution. Putting facts on one side we saw that, as a theory, Special Creation involved the unthinkable. Not taking into consideration external support, it was demonstrated that the hypothesis had not sufficient internal strength to support itself. These objections cannot be urged against Evolution. This theory does not involve the unthinkable. Whereas the antagonistic view compels us to attempt to conceive of the creation of matter and the creation of motion; Evolution, having only to do with matter and motion, finds them ready to its hand. To the Evolutionist both matter and motion are eternal. There has been no creation of the one or of the other. And here he is supported again by all evidence. Nobody has ever seen matter created; nobody has ever seen matter destroyed. And the same statements may be made with respect to motion. If it be urged that it is as impossible to conceive of the eternity of matter as it is to conceive of an eternal god, the answer is that we have seen, touched, tasted, handled matter. It is here by our side, indeed we *are* but forms of it. On the other hand there has never been any sense-evidence whatever of deity. So that the evolutionist believes in the eternal nature of some thing that actually is, with which his every moment's experience brings him into contact, and that he has never yet seen either created or destroyed, whilst the special creationist believes in the eternal nature of something of which he has no sense-evidence whatever, of something into contact with which he has never come.

Again it is urged by our opponents that Evolution is not reasonable because it is impossible to conceive of the greatly complex human being, for example, having been evolved in the course of ages out of simple protoplasm. In reply to this, on the one hand even such a conception as this, unsupported by evidence, is less difficult than the conception of the creation of such a human being out of nothing. But a still stronger answer is that this evolution of a complex human being out of a piece of protoplasm is seen—actually seen to occur, not during the course of countless ages, but in some twenty-one years. Every man against whom your brush in the streets has been absolutely developed from such a piece of protoplasm. The first condition of the human being is nothing more nor less than a protoplasmic plastid. In some twenty years that, passing through stage after stage of development, becomes an adult man. If then in so short a time, under favorable conditions, such a development can take place, who will dare to question the possibility of like developments having occurred during the inconceivably numerous ages that nature has been at work in the past?

E. The pain question. When we consider the amount of agony that is in the world, as Evolutionists, whilst we sorrow as we behold, we have not the duty laid upon us of explaining its presence. Our sole duty is to use all effort to diminish the amount of pain. He that believes in the omnipotent and the all-good is impaled on one of the two horns of a frightful dilemma. As has been so often pointed out, either his god has not been able to prevent evil, and then he is not omnipotent, or he has been able to prevent, but has been unwilling, and then he is not good. Into this dilemma that we may fairly call terrible, and that is not the less terrible from the blindness to its very nature on the part of those that are struggling in it, the Evolutionist is not plunged. Having no conception of an outside beneficent power that superintends every detail of the history of the universe, he has not before him the impossible task of reconciling the existence of such power with the world's moaning and tears. He accepts the presence of the pain, and gives all energy of body and mind to the lessening thereof.

CHAPTER XI.

ARCHEBIOSIS.

THIS series of discussions upon the recent discoveries and the present problems of Biological Science will close with a brief investigation of a subject literally of vital interest. That is, the question as to the origin of life. The difficulty of the subject has always surrounded it with an air of more than usual mystery. The Special Creationists are hereabouts very dogmatic and gleeful. They say, rightly enough, that Evolution, if it be the great principle, ought to explain not only the origin of living beings one from another, but the origin of living matter from non-living. This they consider impossible. It is assuredly difficult, but it is growing more possible every hour; and it is well to remind them, in their dogmatism and their glee, that their own statements are, by no manner of means, explanations. There is not the faintest satisfaction in saying that living matter could not have evolved from non-living, but that god created the living being. There is no explanation in these phrases. So the Evolutionist, believing in his creed, bends himself to the hard task of applying it to this most intricate question.

The origin of life is called Archebiosis (from αρχη= begining, βιος=life). In common phraseology it is Spontaneous generation, a name altogether bad. "Spontaneous" has no meaning in science to-day. Granted matter and motion as eternal, and therefore uncaused, there is no evidence of, and therefore there can be no belief in, the occurrence of uncaused, isolated phænomena. If ever the phrase unfortunately creeps into any scientific writing, it can only imply that the reason of the phænomenon thus named is not at present understood. When Charles Darwin speaks of "spontaneous variation," he is careful to explain that by the phrase he means variation whose causes are at present unknown to him. Let us, therefore, discard the unfortunate phrase Spontaneous generation, and always speak of the origin of living matter as Archebiosis.

In discussing the question I shall consider: A, The matter concerned; B, The principle of the conservation of energy; C, Certain facts bearing on the subject; D, Experiments.

A. The matter concerned. As has been pointed out in earlier pages, the conception of the origin of living matter was exceedingly difficult as long as the belief was held that its simplest forms were really of a very complex nature. As long as the cell was regarded as the simplest form of living matter, so long there was great difficulty in conceiving the possibility of its originating from non-living. But we have seen that far from the cell being the most simple, it is indeed a very complex form. Nobody to-day denies the possession of life to the cytod, or non-nucleated cell, or to the plastid or mass of protoplasm unsurrounded by any wall. He that has observed under the microscope the exceedingly minute pieces of structureless protoplasm that are at present our simplest forms of living matter, will recognise that the step from them to non-living is but a brief one.

B. Conservation of energy. A full belief in the principle of the conservation of energy impels to a belief in the evolution of life. That principle teaches that neither matter nor motion can be created or destroyed. And therefore we are driven to believe that the first form of living matter can only have been some modification of pre-existent forms of matter. We are driven to believe that the particular kind of movements which it exhibits, and which we name "vital," are only modifications of pre-existent forms of motion, so that the living thing is nothing but non-living matter so modified that a new name must be applied, and it is called "Organic." But we no more conceive that there is a special creation of living matter than we conceive water is a special creation when the two matters called Hydrogen and Oxygen are combined. We no more conceive of a special creation of movements called vital than we conceive the properties of water as especially created, or as any other than the results of the properties of its constituents mutually interacting. It is true that very many of these same "vital" properties appear together uncalculable from the properties of the matter of the living body. But I would urge that equally uncalculable at first are the results of the interaction upon each other of the properties of non-living substances. Taking a familiar illustration, who could ever have predicted before experiment that two forces acting upon a body should make that body move along the diagonal of a parallelogram whose two adjacent sides represent in magnitude and direction the two forces? All the world knows to-day the principle of the parallelogram of forces, and is almost inclined to call it a self evident proposition. It is by no manner of means self evident. No one could have foretold what would be the result of the combination of these two motions until that result was seen. Or again, given a piece of copper and a few drops of nitric acid, who could possibly tell from the properties of the metal or of the acid what would be the result of putting them together. Now-a-days we know that the copper dissolves, a green liquid is formed, and a gas rapidly becoming brown is given off. This could not have been anticipated. Nor are the copper nitrate and the oxide of nitrogen that are formed (with properties quite different from those of the copper or the acid) labelled with any mystic name such as "vital." And so with the results of putting together of certain pieces of matter in what are called living bodies. Strange, very momentous results follow assuredly, but they follow as the results of the properties of the matters which are brought into contact with their fellows. In this case as in the other two there is no evidence whatever of a special intervention from without.

C. Facts. From a very large number of facts telling in favor of the possibility of the evolution of living from non-living things I select three sets.

(1) Crystals. The whole of the phænomena of crystallisation seem to be analogous to the formation of living organisms out of non-living matter. Dissolved in water are certain salts. There is no trace whatever of definite geometrical solid forms. And yet as the water evaporates, slowly are produced bodies of definite geometrical shape which we call crystals. So much matter in one form is transferred into so much matter in another form. No loss and no creation. Very markedly different results obtain. No one

will speak of a crystalline force being specially created to determine this formation.

(2) The healing of wounds. A man is from some cause suffering from a large open wound. From the blood vessels around is poured out what the doctors call "organisable lymph," a fluid that examined never so carefully under the microscope presents no trace of the structures that are to be restored. And yet very rapidly this organisable lymph becomes transformed into tissue—muscle, nerve, skin—and the parts are restored.

(3) The Food Cycle. The mineral kingdom is the food supplier to the vegetable kingdom. The majority of plants feed upon inorganic matters, such as carbonic acid, water and ammonia. No special creation is dreamed of as necessary for the conversion of these inorganic substances into the materials of the living plant. Nay! we may go farther. The animal kingdom, even its very highest member, man, in building up the living structures builds them up out of dead matter. True the food, say of a man, is in the main organic in its nature. It is either vegetable or animal, but it is dead vegetable or dead animal matter. When a man takes food into his body, that food is not living, and yet by the processes of digestion, absorption and nutrition, gradually the dead food is transformed into living muscle or living brain. Here, again, nobody dreams of any special creation stepping in to convert the dead matter into living. In all these cases, and especially in the last, Archebiosis is actually seen to occur—that is, living matter is seen to be formed out of non-living. Just as we have been led to believe that as individual animals and plants to-day are seen to be evolved, and not created, therefore, probably in the past all plants and animals have been evolved and not created, so when we see to-day living matter being formed out of non-living, and do never see living matter specially created, we are entitled to believe that all forms of living matter have been in the past formed from non-living, and that none has been specially created.

D. Experiments. I am aware that the enthusiastic advocates of Special creation hurl at the heads of the believers in Archebiosis, the experiments of Pasteur and Huxley and Tyndall. Let me say at once that these experiments, to my mind, prove absolutely nothing. Let us look clearly at the two best sets of experiments. Various observers hermetically seal inorganic matter away from contact with the air. One observer finds afterwards nothing but inorganic matter. Another finds living beings in the infusion. Or, again, air that has been passed through red-hot tubes, or through sulphuric acid is admitted into solutions containing non-living matter. After various raisings of the temperature to which the air must be subjected, necessitated by the persistence with which organic forms would appear—after various devices whereby the air was subjected to the most rigorous treatment, at length certain experiments have arrived at conditions that appear to prevent the formation of organic matter. Air that has been tremendously heated, and treated with acid and so forth, if admitted into solutions of inorganic matter, does not, say they, allow of the production of living things in those solutions. This result is explained by saying that the heating and the acid have destroyed the "invisible germs of living matter." It is the strangest of theories this of invisible germs! It is surely a case of special creation again. There is of these invisible germs absolutely no evidence whatever. What is the explanation of the absence of organic matter in solutions visited by the maltreated air given by him that believes in Archebiosis? He tells you that the air thus roughly dealt with—by high temperature and acid vapors—has had its properties changed. You cannot treat any gas in this harsh fashion without considerably altering its normal properties. It is at least as fair to assume that normal air passing into a normal solution of inorganic salts would, by a reaction of its properties upon those of the salts, produce a form of matter with new properties that you would denote living, as to assume that that air carries invisible germs of living matter. On the one view, I repeat, the harsh treatment of the air destroys invisible germs that nobody has ever seen, and of which there is no proof; on the other view, that harsh treatment modifies the properties of the air to so great an extent that its normal reaction upon other inorganic matters cannot take place. And finally, whilst inductively the evidence is at least as strong in favor of the one view as the other, deductively but one conclusion appears to be open. We accept Evolution as to the origin of man, as to the origin of the so-called lower animals, as to the origin of plants. Who is to be the Cnut to say to this great sea, "Thus far shalt thou go, and no farther!" If the great principle be true as to the origin of living things from living things, the hypothesis that it will be true as to the origin of living things as a whole becomes highly probable. We trace it back from highest to lowest, and where the lowest living thing in its structure and in its properties is gliding into the non-living, surely we are entitled to believe that the same principle obtains, and that living matter has been evolved from non-living. Then bursts in upon the view Evolution in all its glory. Then comes the inspiring belief that not only is man connected by indissoluble blood ties with other animals, and through them with the great world of trees and flowers, but that he is linked on through a long ancestral pedigree to the very rocks, and seas, and stars. Then through his being stirs the pulse that moves throughout the whole universe. Then, indeed, his brotherhood with all things becomes most wide-reaching and everlasting.

THE END.

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